


DECLARATION

I, Hikaru MORIOKA, 1-17, Uchiya 3-chome, Minami-ku, Saitama-shi, Saitama, Japan, do hereby declare that I am familiar with the English and Japanese Languages and that I believe the annexed is an accurate translation of the certified copy of the Japanese Patent Application No.2002-247338, filed on August 27, 2002.

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Abstract

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                  【NEED FOR PROOF】

Necessary

5                   【TITLE OF THE DOCUMENT】                   SPECIFICATION

                  【TITLE OF THE INVENTION】 BARREL-ADVANCING CAM MECHANISM  
OF A ZOOM LENS, AND BARREL-ADVANCING CAM MECHANISM

                  【CLAIMS】

                  1.     A barrel-advancing cam mechanism of a zoom  
10    lens which includes: a rotatable cam ring having a  
plurality of cam grooves formed on a peripheral surface  
of said cam ring; and a linearly movable ring movable by  
said cam ring along an optical axis without rotating by  
engagement of said plurality of cam grooves with a  
15    plurality of cam followers of said linearly movable ring  
when said cam ring is rotated, said linearly movable ring  
supporting at least one optical element of a  
photographing optical system,

                  wherein said plurality of cam grooves are located  
20    at different positions at least in said optical axis  
direction and which trace substantially a same reference  
cam diagram, while all cam grooves of said plurality of  
cam grooves are partial cam grooves each having at least  
one end opening at at least one of opposite ends of said  
25    cam ring, so as not to include an entire portion of said



reference cam diagram,

wherein said plurality of cam followers are located at different positions at least in said optical axis direction and are respectively engageable in said plurality of cam grooves, and

wherein at least one of said plurality of cam followers remains engaged in a corresponding said cam groove while at least one of the other of said plurality of cam followers comes out of said end opening and is disengaged therefrom, when said linearly movable ring moves to at least one of opposite limits for movement thereof in said optical axis direction.

2. The barrel-advancing cam mechanism according to claim 1, wherein said plurality of cam grooves comprises a front cam groove having at least one front end opening at a front end of said cam ring so as not to include a front part of said entire portion of said reference cam diagram, and a rear cam groove having at least one rear end opening at a rear end of said cam ring so as not to include a rear part of said entire portion of said reference cam diagram,

wherein said cam followers comprise a front cam follower and a rear cam follower which are engaged in said front cam groove and said rear cam groove, respectively,

wherein said front cam follower comes out of said

front opening to be disengaged from said front cam groove while said rear cam follower remains engaged in said rear cam groove when said linearly movable ring moves to a front limit for movement thereof in said optical axis direction, and

wherein said rear cam follower comes out of said rear opening to be disengaged from said rear cam groove while said front cam follower remains engaged in said front cam groove when said linearly movable ring moves to a rear limit for movement thereof in said optical axis direction.

3. The barrel-advancing cam mechanism according to claim 1 or 2, further comprising:

a plurality of cam groove groups, each said cam groove group comprising said plurality of cam grooves located at different positions in said optical axis direction, said plurality of cam groove groups located at different positions in a circumferential direction of said cam ring; and

a plurality of cam follower groups, each said cam follower group comprising said complementing cam followers provided at different positions in said optical axis direction, said plurality of cam follower groups located at different positions in a circumferential direction of said linearly movable ring.

4. A lens-barrel-advancing cam mechanism of a zoom lens which includes: a rotatable cam ring having a pair of cam grooves formed on a peripheral surface of said cam ring; and a linearly movable ring movable by said cam ring along an optical axis without rotating by engagement of said pair of cam grooves with a pair of cam followers of said linearly movable ring when said cam ring is rotated, said linearly movable ring supporting at least one optical element of a photographing optical system, wherein said pair of cam grooves are located at different positions at least in said optical axis direction and which trace substantially a same reference cam diagram, while said pair of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of said cam ring, so as not to include an entire portion of said reference cam diagram,

wherein said pair of cam followers are located at different positions at least in said optical axis direction and are respectively engageable in said pair of cam grooves, and

wherein one of said pair of cam followers remains engaged in a corresponding said cam groove while the other of said pair of cam followers comes out of said end opening and is disengaged therefrom, when said linearly

movable ring moves to at least one of opposite limits for movement thereof in said optical axis direction.

5. A barrel-advancing cam mechanism including:  
a rotatable cam ring having a plurality of cam grooves  
5 formed on a peripheral surface of said cam ring; and a  
linearly movable ring movable by said cam ring along a  
rotational axis of said cam ring without rotating by  
engagement of said plurality of cam grooves with a  
plurality of cam followers of said linearly movable ring  
10 when said cam ring is rotated,

wherein said plurality of cam grooves are located  
at different positions at least in said rotational axis  
direction and which trace substantially a same reference  
cam diagram, while all cam grooves of said plurality of  
15 cam grooves are partial cam grooves each having at least  
one end opening at at least one of opposite ends of said  
cam ring, so as not to include an entire portion of said  
reference cam diagram,

wherein said plurality of cam followers are located  
20 at different positions at least in said rotational axis  
direction and are respectively engageable in said  
plurality of cam grooves, and

wherein at least one of said plurality of cam  
followers remains engaged in a corresponding said cam  
25 groove while at least one of the other of said plurality

of cam followers comes out of said end opening and is disengaged therefrom, when said linearly movable ring moves to at least one of opposite limits for movement thereof in said rotational axis direction.

5    【DETAILED DESCRIPTION OF THE INVENTION】

          【0001】

          【Technical Field】

          The present invention relates to a barrel-advancing cam mechanism using a cam ring and a linearly movable  
10   ring, and more specifically to a lens moving mechanism of a zoom lens which uses a cam ring.

          【0002】

          【Prior Art and Problems Thereof】

          Miniaturization of cameras has been in increasing  
15   demand. In a retractable lens barrel which advances and retracts one or more lens groups by rotation of a cam ring, it has been desired to reduce the length of the cam ring while securing a sufficient range of movement of each movable lens group in an optical axis direction. In  
20   addition, a barrel-advancing cam mechanism which satisfies such an antinomic demand has also been desired in technical fields other than the technical field of zoom lenses.

          【0003】

25        【Objective of the Invention】

An object of the present invention is to provide a barrel-advancing cam mechanism, having a cam ring and used in a zoom lens, wherein the cam mechanism incorporates a small cam ring without sacrificing the range of movement of one or more movable lens groups. Another object of the present invention is to provide a barrel-advancing cam mechanism, having a cam ring, wherein the cam mechanism incorporates a small cam ring without sacrificing the range of movement of the linearly movable member.

【0004】

【Summary of the Invention】

A barrel-advancing cam mechanism of a zoom lens according to the present invention has been made on the premise that the barrel-advancing cam mechanism includes: a rotatable cam ring having a plurality of cam grooves formed on a peripheral surface of the cam ring; and a linearly movable ring movable by the cam ring along an optical axis without rotating by engagement of the plurality of cam grooves with a plurality of cam followers of the linearly movable ring when the cam ring is rotated, the linearly movable ring supporting at least one optical element of a photographing optical system. The plurality of cam grooves are located at different positions at least in the optical axis direction and

which trace substantially a same reference cam diagram,  
while all cam grooves of the plurality of cam grooves are  
partial cam grooves each having at least one end opening  
at at least one of opposite ends of the cam ring, so as  
5 not to include an entire portion of the reference cam  
diagram. On the other hand, the plurality of cam  
followers are located at different positions at least in  
the optical axis direction and are respectively  
engageable in the plurality of cam grooves. And also,  
10 at least one of the plurality of cam followers remains  
engaged in a corresponding the cam groove while at least  
one of the other of the plurality of cam followers comes  
out of the end opening and is disengaged therefrom, when  
the linearly movable ring moves to at least one of  
15 opposite limits for movement thereof in the optical axis  
direction. This structure makes it possible to give the  
linearly movable ring an amount of movement greater than  
the length of the cam ring in the optical axis direction.  
The cam mechanism can operate if only it is provided with  
20 at least one pair of cam grooves and corresponding at  
least one pair of cam followers.

【0005】

More preferably, the plurality of cam grooves  
comprises a front cam groove having at least one front  
25 end opening at a front end of the cam ring so as not to

include a front part of the entire portion of the  
reference cam diagram, and a rear cam groove having at  
least one rear end opening at a rear end of the cam ring  
so as not to include a rear part of the entire portion  
5 of the reference cam diagram, wherein the cam followers  
comprise a front cam follower and a rear cam follower  
which are engaged in the front cam groove and the rear  
cam groove, respectively, wherein the front cam follower  
comes out of the front opening to be disengaged from the  
10 front cam groove while the rear cam follower remains  
engaged in the rear cam groove when the linearly movable  
ring moves to a front limit for movement thereof in the  
optical axis direction, and wherein the rear cam follower  
comes out of the rear opening to be disengaged from the  
15 rear cam groove while the front cam follower remains  
engaged in the front cam groove when the linearly movable  
ring moves to a rear limit for movement thereof in the  
optical axis direction.

【0006】

20 To support the linearly movable ring with  
stability, it is desirable that the barrel-advancing cam  
mechanism further includes: a plurality of cam groove  
groups, each cam groove group comprising the plurality  
of cam grooves located at different positions in the  
25 optical axis direction, the plurality of cam groove



groups located at different positions in a circumferential direction of the cam ring; and a plurality of cam follower groups, each cam follower group comprising the complementing cam followers provided at 5 different positions in the optical axis direction, the plurality of cam follower groups located at different positions in a circumferential direction of the linearly movable ring.

【0007】

10 The present invention can also be applied to various barrel-advancing cam mechanisms of any technical fields other than the technical field of the zoom lenses, by making the linearly movable ring support a member other than one or more optical elements of a photographing 15 optical system.

【0008】

【Embodiment】

Firstly, the overall structure of an embodiment of a zoom lens 71 according to the present invention will 20 be hereinafter described below with reference to Figures 1 through 18. This embodiment of the zoom lens 71 is incorporated in a digital camera 70, and is provided with a photographing optical system consisting of a first lens group LG1, a shutter S, an adjustable diaphragm A, a 25 second lens group LG2, a third lens group LG3, a low-pass

filter (and the like) LG4, and a solid-state image  
pick-up device (CCD) 60. "Z1" shown in the drawings  
designates the optical axis of the photographing optical  
system. The photographing optical axis Z1 is parallel  
5 to a lens barrel axis Z0 of the zoom lens 71, and is  
decentered with respect to the lens barrel axis Z0. In  
the following descriptions, the term "optical axis  
direction" means a direction parallel to the  
photographing optical axis Z1 unless there is a different  
10 explanatory note on the expression.

【0009】

As shown in Figures 6 and 7, the camera 70 is  
provided in the camera body 72 thereof with a stationary  
barrel 22 fixed to the camera body 72, and a CCD holder  
15 21 fixed to a rear portion of the stationary barrel 22.  
The CCD image sensor 60 is mounted to the CCD holder 21  
to be held thereby via a CCD base plate 62. The low-pass  
filter LG4 is held by the CCD holder 21 to be positioned  
in front of the solid-state image pick-up device 60 via  
20 a filter holder 73 and an annular sealing member 61.

【0010】

The zoom lens 71 is provided in the stationary  
barrel 22 with an AF lens frame (a third lens frame which  
supports and holds the third lens group LG3) 51 which is  
25 guided linearly in the optical axis direction without

rotating about the photographing optical axis Z1.  
Specifically, the zoom lens 71 is provided with a pair  
of AF guide shafts 52 and 53 which extend parallel to the  
photographing optical axis Z1 to guide the AF lens frame  
5 51 in the optical axis direction without rotating the AF  
lens frame 51 about the photographing optical axis Z1.  
Front and rear ends of each guide shaft of the pair of  
AF guide shafts 52 and 53 are fixed to the stationary  
barrel 22 and the CCD holder 21, respectively. The pair  
10 of AF guide shafts 52 and 53 are respectively fitted into  
a pair of guide holes so that the AF lens frame 51 is  
slidable on the pair of AF guide shafts 52 and 53. In  
this particular embodiment, the AF guide shaft 52 serves  
as a main guide shaft, while the AF guide shaft 53 serves  
15 as a member for preventing the AF lens frame 51 from  
rotating. An AF motor 160 having a rotary drive shaft is  
threaded to serve as a feed screw shaft, and this rotary  
drive shaft is screwed through a screw hole formed on an  
AF nut 54 fixed to the AF lens frame 51. Due to this  
20 structure, rotating the rotary drive shaft forward and  
rearward causes the AF lens frame 51 to move forward and  
rearward in the optical axis direction by engagement of  
the rotary drive shaft (feed screw shaft) with the AF nut  
54. The AF lens frame 51 is biased forward in the optical  
25 axis direction by an AF-frame biasing spring 55.

-----  
[0011]

As shown in Figure 5, a zoom motor 150 and a reduction gear train box 74 are mounted on the stationary barrel 22. The reduction gear train box 74 contains a  
5 reduction gear train for transferring rotation of the zoom motor 150 to a zoom gear 28. The zoom gear 28 is pivoted to the stationary barrel 22 by a zoom gear shaft 29 which extends parallel to the photographing optical axis Z1. Rotations of the zoom motor 150 and the AF motor  
10 160 are controlled by a control circuit of the digital camera via a flexible PWB (printed wiring board) 75 which is positioned on an outer peripheral surface of the stationary barrel 22.

[0012]

15 The stationary barrel 22 is provided on an inner peripheral surface thereof with a female helicoid 22a, a set of three linear guide grooves 22b, a set of three lead grooves 22c, and a set of three rotational sliding grooves 22d. The set of three linear guide grooves 22b  
20 extend parallel to the photographing optical axis Z1. The set of three lead grooves 22c extend parallel to the female helicoid 22a. The set of three rotational sliding grooves 22d are formed in the vicinity of a front end of the inner peripheral surface of the stationary  
25 barrel 22 to extend along a circumference of the

stationary barrel 22 to communicate the front ends of the  
set of three lead grooves 22c, respectively. The female  
helicoid 22a is not formed on that specific front area  
of the stationary barrel 22 on which the set of three  
5 rotational sliding grooves 22d are formed.

【0013】

A helicoid ring 18 is provided on an outer  
peripheral surface thereof with a male helicoid 18a and  
a set of three rotational sliding projections 18b. The  
10 male helicoid 18a is engaged with the female helicoid  
22a, and the set of three rotational sliding projections  
18b are engaged in the set of three lead grooves 22c or  
the set of three rotational sliding grooves 22d,  
respectively (see Figures 4 and 12). The helicoid ring  
15 18 is provided on threads of the male helicoid 18a with  
an annular gear 18c which is in mesh with the zoom gear  
28. Therefore, when a rotation of the zoom gear 28 is  
transferred to the annular gear 18c, the helicoid ring  
18 moves forward or rearward in the optical axis  
20 direction while rotating within a predetermined range in  
which the female helicoid 22a remains in mesh with the  
male helicoid 18a. A forward movement of the helicoid  
ring 18 beyond a predetermined point causes the annular  
gear 18c to be disengaged from the zoom gear 28 so that  
25 the helicoid ring 18 rotates about the lens barrel axis

20 without moving in the optical axis direction relative  
to the zoom gear 28 by engagement of the set of three  
rotational sliding projections 18b with the set of three  
rotational sliding grooves 22d. The stationary barrel 22  
5 is provided with a stop-member insertion hole 22e which  
radially penetrates one rotational sliding groove 22d  
and an outer peripheral surface of the stationary barrel  
22. A barrel stop member 26 for preventing the helicoid  
ring 18 from rotating beyond a photographing range  
10 thereof is detachably attached to the stop-member  
insertion hole 22e.

【0014】

The helicoid ring 18 is provided, on an inner front  
peripheral surface thereof at three different  
15 circumferential positions on the helicoid ring 18, with  
three rotation transfer recesses 18d (see Figures 4 and  
10), while the third external barrel 15 is provided, at  
corresponding three different circumferential positions  
on the third external barrel 15, with three pairs of  
20 rotation transfer projections 15a (see Figures 4 and 11)  
which project rearward from the rear end of the third  
external barrel 15 to be inserted into the three rotation  
transfer recesses 18d from the front thereof,  
respectively. The three pairs of rotation transfer  
25 projections 15a and the three rotation transfer recesses

18d are movable relative to each other in a direction of  
the lens barrel axis Z0, and are not rotatable relative  
to each other about the lens barrel axis Z0. Namely, the  
helicoid ring 18 and the third external barrel 15 rotate  
5 in one piece. The helicoid ring 18 is provided on the  
three rotational sliding projections 18b with a set of  
three engaging recesses 18e which are formed on an inner  
peripheral surface of the helicoid ring 18. The third  
external barrel 15 is provided with a set of three  
10 engaging projections 15b which are engaged in the set of  
three engaging recesses 18e, respectively. The set of  
three engaging projections 15b, which are respectively  
engaged in the set of three engaging recesses 18e, are  
also engaged in the set of three rotational sliding  
15 grooves 22d at a time, respectively, when the set of three  
rotational sliding projections 18b are engaged in the set  
of three rotational sliding grooves 22d (see an upper  
half of the zoom lens in Figure 6).

【0015】

20 The zoom lens 70 is provided between the third  
external barrel 15 and the helicoid ring 18 with three  
compression coil springs 25 which bias the third external  
barrel 15 and the helicoid ring 18 in opposite directions  
away from each other in the optical axis direction. The  
25 rear ends of the three compression coil springs 25 are

respectively inserted into three spring insertion  
recesses 18f which are formed on the front end of the  
helicoid ring 18, while the front ends of the three  
compression coil springs 25 are respectively in pressing  
5 contact with three engaging recesses 15c formed at the  
rear end of the third external barrel 15. Therefore, the  
set of three engaging projections 15b of the third  
external barrel 15 are respectively pressed against  
front surfaces in the set of three rotational sliding  
10 grooves 22d by the spring force of the three compression  
coil springs 25, while the set of three rotational  
sliding projections 18b of the helicoid ring 18 are  
respectively pressed against rear guide surfaces in the  
set of three rotational sliding grooves 22d by the spring  
15 force of the three compression coil springs 25. This  
removes backlash of the third external barrel 15 and the  
helicoid ring 18 with respect to the stationary barrel  
22.

**【0016】**

20 The third external barrel 15 is provided on an inner  
peripheral surface thereof with a plurality of relative  
rotation guide projections 15d which are formed at  
different circumferential positions on the third  
external barrel 15, a circumferential groove 15e which  
25 extends in a circumferential direction about the lens



barrel axis Z0, and a set of three rotation transfer grooves 15f which extend parallel to the lens barrel axis Z0 (see Figures 4 and 11). The circumferential positions of the three rotation transfer grooves 15f are formed to correspond to those of the three pairs of rotation transfer projections 15a, respectively. The rear end of each rotation transfer groove 15f is open at the rear end of the third external barrel 15. The helicoid ring 18 is provided on an inner peripheral surface thereof with a circumferential groove 18g which extends in a circumferential direction about the lens barrel axis Z0 (see Figures 4 and 10). The zoom lens is provided inside the third external barrel 15 and the helicoid ring 18 with a first linear guide ring 14. The first linear guide ring 14 is provided on an outer peripheral surface thereof with a set of three linear guide projections 14a, a first plurality of relative rotation guide projections 14b, a second plurality of relative rotation guide projections 14c, and a circumferential groove 14d in this order from rear to front of the first linear guide ring 14 in the optical axis direction (see Figures 4 and 12). The set of three linear guide projections 14a project radially outwards. The first plurality of relative rotation guide projections 14b project radially outwards at different

circumferential positions on the first linear guide ring 14, and the second plurality of relative rotation guide projections 14c project at different circumferential positions on the first linear guide ring 14. The  
5 circumferential groove 14d is an annular groove with its center on the lens barrel axis 20. The first linear guide ring 14 is guided in the optical axis direction with respect to the stationary barrel 22 by engagement of the set of three linear guide projections 14a with the set  
10 of three linear guide grooves 22b, respectively. The third external barrel 15 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis 20 relative to the first linear guide ring 14 by both the engagement of the second plurality of relative rotation  
15 guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. The second plurality of relative rotation guide projections 14c and the circumferential groove 15e  
20 are engaged with each other to be slightly movable relative to each other in the optical axis direction. Likewise, the plurality of relative rotation guide projections 15d and the circumferential groove 14d are engaged with each other to be slightly movable relative  
25 to each other in the optical axis direction. The

helicoid ring 18 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis 20 relative to the first linear guide ring 14 by engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g. The first plurality of relative rotation guide projections 14b and the circumferential groove 18g are engaged with each other to be slightly movable relative to each other in the optical axis direction.

10       【0017】

The first linear guide ring 14 is provided with a set of three guide slots 14e which radially penetrate the first linear guide ring 14. As shown in Figure 12, each guide slot 14e includes a front circumferential slot portion 14e-1, a rear circumferential slot portion 14e-2, and a lead slot portion 14e-3 which connects the front circumferential slot portion 14e-1 with the rear circumferential slot portion 14e-2. The front circumferential slot portion 14e-1 and the rear circumferential slot portion 14e-2 extend parallel to each other in a circumferential direction of the first linear guide ring 14. The lead slot portion 14e-3 extends parallel to the threads of the female helicoid 22a. A set of three followers 32 fixed to an outer peripheral surface of a cam ring 11 at different

circumferential positions thereon are engaged in the set of three guide lots 14e, respectively. Each roller follower 32 is fixed to the cam ring 11 by set screw 32a. The set of three followers 32 are further engaged in the set of three rotation transfer grooves 15f through the set of three guide lots 14e, respectively. A set of three follower pressing protrusions 17a protrude rearward from a roller-biasing spring 17 to be engaged in front portions of the set of three rotation transfer grooves 15f, respectively (see Figure 11). The set of three follower pressing protrusions 17a press the set of three followers 32 rearward to remove backlash between the set of three followers 32 and the set of three guide lots 14e when the set of three followers 32 are engaged in the front circumferential slot portions 14e-1 of the set of three guide lots 14e, respectively.

【0018】

Advancing operations of movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 will be understood with reference to the above described structure of the digital camera 70. Namely, rotating the zoom gear 28 in a lens barrel advancing direction by the zoom motor 150 causes the helicoid ring 18 to move forward while rotating about the lens barrel axis 20 due to engagement of the female helicoid 22a with

the male helicoid 18a. This rotation of the helicoid ring 18 causes the third external barrel 15 to move forward together with the helicoid ring 18 while rotating about the lens barrel axis Z0 together with the helicoid ring 18, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15 because each of the helicoid ring 18 and the third external barrel 15 is coupled to the first linear guide ring 14 to make respective relative rotations between the third external barrel 15 and the first linear guide ring 14 and between the helicoid ring 18 and the first linear guide ring 14 possible and to be movable together along a direction of a common rotational axis (i.e., the lens barrel axis Z0) due to the engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g, the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. Rotation of the third external barrel 15 is transferred to the cam ring 11 via the set of three rotation transfer grooves 15f and the set of three followers 32, which are engaged in the set of three rotation transfer grooves 15f,

respectively. Since the set of three followers 32 are also engaged in the set of three guide lots 14e, respectively, the cam ring 11 moves forward while rotating about the lens barrel axis 20 relative to the first linear guide ring 14 in accordance with contours of the lead slot portions 14e-3 of the set of three guide lots 14e. Since the first linear guide ring 14 itself moves forward together with the third lens barrel 15 and the helicoid ring 18 as described above, the cam ring 11 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by engagement of the set of three followers 32 with the lead slot portions 14e-3 of the set of three guide lots 14e, respectively.

【0019】

The above described rotating-advancing operations are performed while the set of three rotational sliding projections 18b are moving in the set of three lead grooves 22c, respectively, when the male helicoid 18a and the female helicoid 22a are engaged with each other. When the helicoid ring 18 moves forward by a predetermined amount of movement, the male helicoid 18a and the female helicoid 22a are disengaged from each

other so that the set of three rotational sliding  
projections 18b move from the set of three lead grooves  
22c to the set of three rotational sliding grooves 22d,  
respectively, while the set of three followers 32 enter  
5 the front circumferential slot portions 14e-1 of the set  
of three guide lots 14e, respectively. Since the  
helicoid ring 18 does not move in the optical axis  
direction relative to the stationary barrel 22 even if  
rotating upon the disengagement of the male helicoid 18a  
10 from the female helicoid 22a, the helicoid ring 18 and  
the third external barrel 15 rotate at respective axial  
fixed positions thereof without moving in the optical  
axis direction. In this state, since the first linear  
guide ring 14 stops while the set of three followers 32  
15 have respectively moved into the front circumferential  
slot portions 14e-1, the cam ring 11 is not given any  
force making the cam ring 11 move forward.  
Consequently, the cam ring 11 only rotates at an axial  
fixed position in accordance with rotation of the third  
20 external barrel 15.

【0020】

Rotating the zoom gear 28 in a lens barrel  
retracting direction thereof causes the aforementioned  
movable elements of the zoom lens 71 from the stationary  
25 barrel 22 to the cam ring 11 to operate in the reverse

manner to the above described advancing operations. In this reverse operation, the above described fundamental movable elements of the zoom lens 71 retract to their respective retracted positions shown in Figure 7 by rotation of the helicoid ring 18 until the set of three followers 32 enter the rear circumferential slot portions 14e-2 of the set of three guide lots 14e, respectively.

【0021】

10 The first linear guide ring 14 is provided on an inner peripheral surface thereof with a set of three pairs of first linear guide grooves 14f which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1, and a set  
15 of six second linear guide grooves 14g which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1. Each pair of first linear guide grooves 14f are position on the opposite sides of the associated linear guide groove  
20 14g (every other linear guide groove 14g) in a circumferential direction of the first linear guide ring 14. A second linear guide ring 10 is provided on an outer edge thereof with a set of three bifurcated projections 10a. Each bifurcated projection 10a (see Figures 3 and  
25 15) is provided at a radially outer end thereof with a



pair of radial projections which are respectively  
engaged in the associated pair of first linear guide  
grooves 14f. On the other hand, a set of six radial  
projections 13a (see Figures 2 and 17) which are formed  
5 on an outer peripheral surface of the second external  
barrel 13 at a rear end thereof to project radially  
outwards are engaged in the set of six second linear guide  
grooves 14g, respectively to be slidable therealong.  
Therefore, each of the second external barrel 13 and the  
10 second linear guide ring 10 is guided in the optical axis  
direction via the first linear guide ring 14.

【0022】

The second linear guide ring 10 serves as a linear  
guide member for guiding a second lens group moving frame  
15 8 linearly without rotating the same, while the second  
external barrel 13 serves as a linear guide member for  
guiding the first external barrel 12 linearly without  
rotating the same. The second lens group moving frame  
8 supports the second lens group LG2. The first external  
20 barrel 12 supports the first lens group LG1.

【0023】

The second linear guide ring 10 is provided on a ring  
portion 10b thereof with a set of three linear guide keys  
10c which project forward (see Figures 3 and 15) from the  
25 ring portion 10b. As shown in Figures 6 and 7, an outer

edge of the ring portion 10b is engaged in a circumferential groove 11e formed on an inner peripheral surface of the cam ring 11 at the rear end thereof to be rotatable about the lens barrel axis Z0 relative to the cam ring 11 and to be immovable relative to the cam ring 11 in the optical axis direction. The set of three linear guide keys 10c project forward from the ring portion 10b to be positioned inside the cam ring 11. Opposite edges of each linear guide key 10c in a circumferential direction of the second linear guide ring 10 serve as parallel guide edges which are respectively engaged with circumferentially-opposed guide surfaces in an associated linear guide groove 8a of the second lens group moving frame 8, which is positioned in the cam ring 11 to be supported thereby, to guide the second lens group moving frame 8 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0. The linear guide grooves 8a are formed on an outer peripheral surface of the second lens group moving frame 8.

【0024】

As shown in Figure 3, the cam ring 11 is provided on an inner peripheral surface thereof with a plurality of cam grooves 11a for guiding the second lens group LG2. A plurality of cam followers 8b which are provided on an

outer peripheral surface of the second lens group moving frame 8 are engaged in the plurality of cam grooves 11a. A rotation of the cam ring 11 causes the second lens group moving frame 8 to move in the optical axis direction in a predetermined moving manner in accordance with contours of the plurality of cam grooves 11a since the second lens group moving frame 8 is guided linearly in the optical axis direction without rotating via the second linear guide ring 10. A guide mechanism for guiding the second lens group moving frame 8 by the plurality of cam grooves 11a will be discussed in detail later.

【0025】

The zoom lens 71 is provided inside the second lens group moving frame 8 with a second lens frame 6. The second lens frame 6 is pivoted on a pivot shaft 33 front and rear ends of which are supported by front and rear second lens frame support plates 36 and 37, respectively. The pair of second lens frame support plates 36 and 37 are fixed to the second lens group moving frame 8 by a set screw 66. The pivot shaft 33 is a predetermined distance away from the photographing optical axis Z1, and extend parallel to the photographing optical axis Z1. The second lens frame 6 is swingable about the pivot shaft 33 between a photographing position shown in Figure 6

where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 and a retracted position shown in Figure 7 where the optical axis of the second lens group LG2 is eccentric from the photographing optical axis Z1. A rotation limit shaft 35 which determines the photographing position of the second lens frame 6 is mounted to the second lens group moving frame 8. The second lens frame 6 is biased to rotate in a direction to come into contact with the rotation limit shaft 35 by a front torsion coil spring 39. A compression coil spring 38 removes backlash of the second lens frame 6 in the optical axis direction.

【0026】

The second lens frame 6 moves together with the second lens group moving frame 8 in the optical axis direction. The CCD holder 21 is provided on a front surface thereof with a position-control cam bar 21a which projects forward from the CCD holder 21 to be engageable with the second lens frame 6 (see Figure 4). If the second lens group moving frame 8 moves rearward in a retracting direction to approach the CCD holder 21, a cam surface formed on a front end surface of the position-control cam bar 21a comes into contact with the second lens frame 6 to rotate the second lens frame 6 to the retracted position.

【0027】

The second external barrel 13 is provided, on an inner peripheral surface thereof for supporting the first lens group LG1, with a set of three linear guide grooves 13b which are formed at different circumferential positions to extend in the optical axis direction. The first external barrel 12 is provided on an outer peripheral surface thereof at the rear end of the first external barrel 12 with a set of three engaging protrusions 12a which are slidably engaged in the set of three linear guide grooves 13b, respectively (see Figures 2, 17 and 18). Accordingly, the first external barrel 12 is guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 via the first linear guide ring 14 and the second external barrel 13. The second external barrel 13 is further provided on an inner peripheral surface thereof in the vicinity of the rear end of the second external barrel 13 with a inner flange 13c which extends along a circumference of the second external barrel 13. The cam ring 11 is provided on an outer peripheral surface thereof a circumferential groove 11c in which the inner flange 13c is slidably engaged so that the cam ring 11 is rotatable about the lens barrel axis Z0 relative to the second external barrel 13 and so that the second

external barrel 13 is immovable in the optical axis

direction relative to the cam ring 11. On the other hand, the first external barrel 12 is provided on an inner peripheral surface thereof with a set of three rollers (cam followers) 31 which projects radially inwards, while the cam ring 11 is provided on an outer peripheral surface thereof with a set of three cam grooves 11b (for guiding the first lens group LG1) in which the set of three rollers 31 are slidably engaged, respectively.

10           【0028】

A first lens frame 1 is supported inside the first external barrel 12 by the first external barrel 12 via a first lens group adjustment ring 2. The first lens group LG1 is supported by the first lens frame 1 to be fixed thereto. The first lens frame 1 is provided on an outer peripheral surface thereof with a male screw thread 1a, and the first lens group adjustment ring 2 is provided on an inner peripheral surface thereof with a female screw thread 2a which is engaged with the male screw thread 1a. The axis position of the first lens frame 1 relative to the first lens group adjustment ring 2 can be adjusted via the male screw thread 1a and the female screw thread 2a.

          【0029】

25           The inner flange 12c of the first external barrel

12 is provided at radially opposite positions thereon  
with respect to the photographing optical axis Z1 with  
a pair of first guide grooves 12b, respectively, while  
the first lens group adjustment ring 2 is provided on an  
5 outer peripheral surface thereof with a corresponding  
pair of guide projections 2b (only one of them appears  
in Figure 2) which project radially outwards in opposite  
directions away from each other to be slidably fitted in  
the pair of first guide grooves 12b, respectively. The  
10 pair of first guide grooves 12b extend parallel to the  
photographing optical axis Z1 so that the combination of  
the first lens frame 1 and the first lens group adjustment  
ring 2 is movable in the optical axis direction with  
respect to the first external barrel 12 by engagement of  
15 the pair of guide projections 2b with the pair of first  
guide grooves 12b. The fixing ring 3 is fixed to the  
first external barrel 12 by the two set screws 64 to close  
the front of the pair of guide projections 2b. The  
fixing ring 3 is provided at radially opposite positions  
20 thereon with respect to the photographing optical axis  
Z1 with a pair of spring receiving portions 3a so that  
a pair of compression coil springs 24 are installed in  
a compressed fashion between the pair of spring receiving  
portions 3a and the pair of guide projections 2b,  
25 respectively. Therefore, the first lens group

adjustment ring 2 is biased rearward in the optical axis direction with respect to the first external barrel 12 by the spring force of the pair of compression coil springs 24. The rear limit for the axial movement of the first lens group adjustment ring 2 with respect to the fixing ring 3 is determined by engagement of a set of four engaging projections 2c of the first lens group adjustment ring 2 with a front surface (which can be seen in Figure 2) of the fixing ring 3 (see an upper half of the zoom lens in Figure 6).

【0030】

The zoom lens 71 is provided between the first and second lens groups LG1 and LG2 with a shutter unit 76 including the shutter S and the adjustable diaphragm A. The shutter unit 76 is positioned in the second lens group moving frame 8 to be supported thereby. The aerial space between the shutter S and the second lens group LG2 is fixed. Likewise, the aerial space between the diaphragm A and the second lens group LG2 is fixed. The zoom lens 71 is provided in front of the shutter unit 76 with a shutter actuator (not shown) for driving the shutter S, and is provided behind the shutter unit 76 with a diaphragm actuator (not shown) for driving the diaphragm A. An exposure control FPC (flexible printed circuit) board 77 extends from the shutter unit 76 to establish



electrical connection between the control circuit and  
each of the shutter actuator and the diaphragm actuator.

【0031】

The zoom lens 71 is provided at the front end of the  
5 first external barrel 12 with a lens barrier mechanism  
which automatically closes a front end aperture of the  
zoom lens 71 when the zoom lens 71 is retracted into the  
camera body 72 to protect the frontmost lens element of  
the photographing optical system of the zoom lens 71,  
10 i.e. the first lens group LG1, from getting stains and  
scratches thereon when the digital camera 70 is not in  
use. The lens barrier mechanism is provided with a pair  
of barrier blades 104 and 105. The pair of barrier  
blades 104 and 105 are rotatable about two pivots  
15 projecting rearward therefrom to be positioned on  
radially opposite sides of the photographing optical  
axis Z1, respectively. The lens barrier mechanism is  
further provided with a pair of barrier blade biasing  
springs 106, a barrier blade drive ring 103, a drive ring  
20 biasing spring 107 and a barrier blade holding plate 102.  
The pair of barrier blades 104 and 105 are biased to  
rotate in opposite directions to be closed by the pair  
of barrier blade biasing springs 106, respectively. The  
barrier blade drive ring 103 is rotatable about the lens  
25 barrel axis Z0, and is engaged with the pair of barrier

blades 104 and 105 to open the pair of barrier blades 104  
and 105 when driven to rotate in a predetermined  
rotational direction. The barrier blade drive ring 103  
is biased to rotate in a barrier opening direction to open  
5 the pair of barrier blades 104 and 105 by the drive ring  
biasing spring 107. The barrier blade holding plate 102  
is positioned between the barrier blade drive ring 103  
and the pair of barrier blades 104 and 105. The spring  
force of the drive ring biasing spring 107 is greater than  
10 the spring force of the pair of barrier blade biasing  
springs 106 so that the barrier blade drive ring 103 is  
held in a specific rotational position thereof to open  
the pair of barrier blades 104 and 105 against the biasing  
force of the pair of barrier blade biasing springs 106  
15 in the state shown in Figure 6 where the zoom lens 71 has  
been extended forward to a point in a zooming range  
(zooming operation performable range) where a zooming  
operation can be carried out. In the course of the  
retracting movement of the zoom lens 71 to the retracted  
20 position shown in Figure 10 from a position in the zooming  
range, the barrier blade drive ring 103 is forcefully  
rotated in a barrier closing direction opposite to the  
aforementioned barrier opening direction by a barrier  
drive ring pressing surface 11d (see Figures 3 and 13).  
25 formed on the cam ring 11. This rotation of the barrier

blade drive ring 103 causes the barrier blade drive ring 103 to be disengaged from the pair of barrier blades 104 and 105 so that the pair of barrier blades 104 and 105 are closed by the spring force of the pair of barrier blade biasing springs 106. The zoom lens 71 is provided immediately in front of the lens barrier mechanism with a lens barrier cover (decorative plate) 101 which covers the front of the lens barrier mechanism.

【0032】

10 A lens barrel advancing operation and a lens barrel retracting operation of the zoom lens 71 having the above described structure will be roughly discussed hereinafter. The stage at which the cam ring 11 is driven to advance from the retracted position to the  
15 position where the cam ring 11 rotates at the axial fixed position without moving in the optical axis direction has been discussed above, and will be briefly discussed hereinafter. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the zoom lens 71  
20 is fully accommodated in the camera body 72 so that the front face of the zoom lens 71 is substantially flush with the front face of the camera body 72. Rotating the zoom gear 28 in the lens barrel advancing direction by the zoom motor 150 causes a combination of the helicoid ring 18  
25 and the third external barrel 15 to move forward while

rotating about the lens barrel axis 20 due to engagement  
of the female helicoid 22a with the male helicoid 18a,  
and further causes the first linear guide ring 14 to move  
forward together with the helicoid ring 18 and the third  
5 external barrel 15. At this time, the cam ring 11 which  
rotates by rotation of the third external barrel 15 moves  
forward in the optical axis direction by an amount of  
movement corresponding to the sum of the amount of the  
forward movement of the first linear guide ring 14 and  
10 the amount of the forward movement of the cam ring 11 by  
a leading structure between the cam ring 11 and the first  
linear guide ring 14 (by engagement of the set of three  
followers 32 with the lead slot portions 14e-3 of the set  
of three guide lots 14e, respectively). Once the  
15 combination of the helicoid ring 18 and the third  
external barrel 15 advances to a predetermined point, the  
male helicoid 18a is disengaged from the female helicoid  
22a while the set of three followers 32 are disengaged  
from the lead slot portions 14e-3 to enter the front  
20 circumferential slot portions 14e-1, respectively.  
Consequently, each of the helicoid ring 18 and the third  
external barrel 15 rotates about the lens barrel axis 20  
without moving in the optical axis direction.

【0033】

25 A rotation of the cam ring 11 causes the second lens

group moving frame 8, which is positioned inside the cam ring 11, to move in the optical axis direction with respect to the cam ring 11 in a predetermined moving manner due to the engagement of the plurality of cam followers 8b with the plurality of cam grooves 11a, respectively. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the second lens frame 6, which is positioned inside the second lens group moving frame 8, has rotated about the pivot shaft 33 to be held in the retracted position above the photographing optical axis Z1 by the position-control cam bar 21a so that the optical axis of the second lens group LG2 moves from the photographing optical axis Z1 to a retracted optical axis Z2 positioned above the photographing optical axis Z1. In the course of movement of the second lens group moving frame 8 from the retracted position to a position in the zooming range, the second lens frame 6 is disengaged from the position-control cam bar 21a to rotate about the pivot shaft 33 from the retracted position to the photographing position shown in Figure 6 where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 by the spring force of the front torsion coil spring 39. Thereafter, the second lens frame 6 remains to be held in the photographing position until

when the zoom lens 71 is retracted into the camera body.

【0034】

In addition, a rotation of the cam ring 11 causes the first external barrel 12, which is positioned around the cam ring 11 and guided linearly in the optical axis direction without rotating, to move in the optical axis direction relative to the cam ring 11 in a predetermined moving manner due to engagement of the set of three rollers 31 with the set of three cam grooves 11b, respectively.

【0035】

Accordingly, an axial position of the first lens group LG1 relative to a picture plane (a light-sensitive surface of the CCD image sensor 60) when the first lens group LG1 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the first external barrel 12 relative to the cam ring 11, while an axial position of the second lens group LG2 relative to the picture plane when the second lens group LG2 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the second lens group moving frame 8 relative to the cam ring

11. A zooming operation is carried out by moving the first and second lens groups LG1 and LG2 on the photographing optical axis Z1 while changing the space therebetween. When the zoom lens 71 is driven to advance from the retracted position shown in Figure 7, the zoom lens 71 firstly goes into a state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at wide-angle extremity. Subsequently, the zoom lens 71 goes into the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at telephoto extremity by a further rotation of the zoom motor 150 in a lens barrel advancing direction thereof. As can be seen from Figure 9, the space between the first and second lens groups LG1 and LG2 when the zoom lens 71 is set at the wide-angle extremity is greater than that when the zoom lens 71 is set at the telephoto extremity. When the zoom lens 71 is set at the telephoto extremity as shown above the photographing lens axis Z1 in Figure 9, the first and second lens groups LG1 and LG2 have moved to approach each other to have some space therebetween which is smaller than the space in the zoom lens 71 set at the wide-angle extremity. This variation of the space between the first and second lens groups LG1 and LG2 for zooming operation is achieved by contours of the plurality of cam

grooves 11a and the set of three cam grooves 11b. In the zooming range between the wide-angle extremity and the telephoto extremity, the cam ring 11, the third external barrel 15 and the helicoid ring 18 rotate at their respective axial fixed positions, i.e., without moving in the optical axis direction.

【0036】

In the zooming range, a focusing operation is carried out by moving the third lens group LG3 (the AF lens frame 51) along the photographing optical axis Z1 by rotation of the AF motor 160 in accordance with an object distance.

【0037】

Driving the zoom motor 150 in a lens barrel retracting direction causes the zoom lens 71 to operate in the reverse fashion to the above described advancing operation to fully retract the zoom lens 71 into the camera body 72 as shown in Figure 7. In the course of this retracting movement of the zoom lens 71, the second lens frame 6 rotates about the pivot shaft 33 to the retracted position by the position-control cam bar 21a while moving rearward together with the second lens group moving frame 8. When the zoom lens 71 is fully retracted into the camera body 72, the second lens group LG2 is retracted into the space radially outside the space in



which the third lens group LG3 and the low-pass filter  
LG4 are retracted as shown in Figure 10, i.e., the second  
lens group LG2 is into an axial range substantially  
identical to an axial range in the optical axis direction  
5 in which the third lens group LG3 and the low-pass filter  
LG4 are positioned. This structure of the camera 70 for  
retracting the second lens group LG2 in this manner  
reduces the length of the zoom lens 71 when the zoom lens  
71 is fully retracted, thus making it possible to reduce  
10 the thickness of the camera body 72 in the horizontal  
direction as viewed in Figure 7.

【0038】

The digital camera 70 is provided with a zoom  
viewfinder the focal length of which varies to correspond  
15 to the focal length of the zoom lens 71. The zoom  
viewfinder is given a driving force from the helicoid  
ring 18 by engagement of a viewfinder drive gear 30 with  
the annular gear 18c of the helicoid ring 18 so that the  
viewfinder drive gear 30 rotates by rotation of the  
20 helicoid ring 18 when the helicoid ring 18 rotates at the  
aforementioned fixed position in the zooming range. The  
zoom viewfinder is provided with a zoom type viewing  
optical system including an objective window plate 81a,  
a first movable power-varying lens 81b, a second movable  
25 power-varying lens 81c, a prism 81d, an eyepiece 81e and

a eyepiece window plate 81f in this order from the object side. The focal length of the zoom viewfinder varies by moving the first movable power-varying lens 81b and the second movable power-varying lens 81c along an optical axis Z3 of the objective optical system of the zoom viewfinder. The optical axis Z3 is parallel to the photographing optical axis Z1. Respective support frames of the first movable power-varying lens 81b and the second movable power-varying lens 81c are linearly guided in a direction of the optical axis Z3 by a guide shaft 82, and each receive a drive force from a screw shaft extending parallel to the guide shaft 82. The digital camera 70 is provided between this screw shaft and the viewfinder drive gear 30 with a reduction gear train. A rotation of the viewfinder drive gear 30 causes the screw shaft to rotate to thereby move the first movable power-varying lens 81b and the second movable power-varying lens 81c forward and rearward. The above described elements of the zoom viewfinder are put together to be prepared as a viewfinder unit (subassembly) 80 which is mounted on top of the stationary barrel 22.

【0039】

[DESCRIPTION OF FEATURES OF THE PRESENT INVENTION]

Features of the present invention will be

hereinafter discussed. In the above described zoom lens, the plurality of cam grooves 11a, which are formed on an inner peripheral surface of the cam ring 11, need reference cam diagrams  $\alpha$ , shown in Figure 14, for giving a necessary movement to the second lens group moving frame (linear moving ring) 8. Each reference cam diagram  $\alpha$  represents the shape of each cam groove of the set of three front cam grooves 11a-1 and the set of three rear cam grooves 11a-2, and includes a lens-barrel operating section and a lens-barrel assembling/disassembling section, wherein the lens-barrel operating section consists of a zooming section and a lens-barrel retracting section. The lens-barrel operating section serves as a control section which controls movement of the second lens group moving frame 8 with respect to the cam ring 11, and which is to be distinguished from the lens-barrel assembling/disassembling section. The zooming section serves as a control section which controls the movement of the second lens group moving frame 8 with respect to the cam ring 11, especially from a position of the second lens group moving frame 8 which corresponds to the wide-angle extremity of the zoom lens 71 to another position of the second lens group moving frame 8 which corresponds to the telephoto extremity of the zoom lens

71, and which is to be distinguished from the lens-barrel retracting section.

【0040】

As can be seen in Figure 27, a length of an axial range W1 of the reference cam diagrams  $\alpha$  in the optical axis direction (the horizontal direction as viewed in Figure 27) is greater than a length W2 of the cam ring 11 in the optical axis direction. The length of the zooming section included in the axial range W1 of the reference cam diagrams  $\alpha$  in the optical axis direction is represented by a length W3. This means that a set of cam grooves each having a sufficient length will not be obtained for the present embodiment of the cam ring 11 if designed according to a conventional method of formation of cam groove wherein a set of long cam grooves which entirely trace a corresponding set of long cam diagrams are formed on a peripheral surface of a cam ring. According to a cam mechanism of the present embodiment of the zoom lens, a sufficient range of movement of the second lens group moving frame 8 in the optical axis direction can be secured without increasing the length of the cam ring 11 in the optical axis direction. The detail of this cam mechanism will be discussed hereinafter.

25 【0041】

As shown in Figure 14, the plurality of cam grooves 11a are composed of a set of three front cam grooves 11a-1 formed at different circumferential positions, and a set of three rear cam grooves 11a-2 formed at different circumferential positions behind the set of three front cam grooves 11a-1. Although each front cam groove 11a-1 and each rear cam groove 11a-2 trace their respective reference cam diagrams  $\alpha$  having the same shape, each front cam groove 11a-1 does not cover the entire range of the associated reference cam diagram  $\alpha$  while each rear cam groove 11a-2 does not cover the entire range of the associated reference cam diagram  $\alpha$  either. A range of each front cam groove 11a-1 which is included in the associated reference cam diagram  $\alpha$  is partly different from a range of each rear cam groove 11a-2 which is included in the associated reference cam diagram  $\alpha$ . Each reference cam diagram  $\alpha$  can be roughly divided into four sections: first through fourth sections  $\alpha 1$  through  $\alpha 4$ . The first section  $\alpha 1$  extends in the optical axis direction. The second section  $\alpha 2$  extends from a first inflection point  $\alpha h$  positioned at the rear end of the first section  $\alpha 1$  to a second inflection point  $\alpha m$  positioned behind the first inflection point  $\alpha h$  in the optical axis direction. The third section  $\alpha 3$  extends from the second inflection point  $\alpha m$  to a third inflection

point  $\alpha_n$  positioned in front of the second inflection point  $\alpha_m$  in the optical axis direction. The fourth section  $\alpha_4$  extends from the third inflection point  $\alpha_n$ . The fourth section  $\alpha_4$  is used only when the zoom lens 5 71 is assembled or disassembled, and is included in both each front cam groove 11a-1 and each rear cam groove 11a-2. Each front cam groove 11a-1 is formed in the vicinity of the front end of the cam ring 11 not to include the entire part of the first section  $\alpha_1$  and a part of 10 the second section  $\alpha_2$ , and is formed to include a front end opening R1 at an intermediate point of the second section  $\alpha_2$  so that the front end opening R1 opens on a front end surface of the cam ring 11. On the other hand, each rear cam groove 11a-2 is formed in the vicinity of 15 the rear end of the cam ring 11 not to include adjoining portions of the second section  $\alpha_2$  and the third section  $\alpha_3$  on opposite sides of the second inflection point  $\alpha_m$ . In addition, each rear cam groove 11a-2 is formed to include a front end opening R4 at the front end of the 20 first section  $\alpha_1$  so that the front end opening R4 opens on a front end surface of the cam ring 11. A missing part of each front cam groove 11a-1 which lies on the associated reference cam diagram  $\alpha$  is included in the associated rear cam groove 11a-2 that is positioned 25 behind the front cam groove 11a-1 in the optical axis

direction, whereas a missing part of each rear cam groove 11a-2 which lies on the associated reference cam diagram  $\alpha$  is included in the associated front cam groove 11a-1 that is positioned in front of the rear cam groove 11a-2 in the optical axis direction. That is, if each front cam groove 11a-1 and the associated rear cam groove 11a-2 are combined into a single cam groove, this signal cam groove will include the entire part of one reference cam diagram  $\alpha$ . The width of each front cam groove 11a-1 and the width of each rear cam groove 11a-2 are the same.

【0042】

Meanwhile, as shown in Figure 16, the plurality of cam followers 8b, which are respectively engaged in the plurality of cam grooves 11a, consist of the set of three front cam followers 8b-1 that are formed at different circumferential positions, and the set of three rear cam followers 8b-2 that are formed at different circumferential positions behind the set of three front cam followers 8b-1 in the optical axis direction, wherein each front cam follower 8b-1 and the rear cam follower 8b-2 positioned therebehind in the optical axis direction are provided as a pair in a manner similar to each pair of cam grooves 11a. The space between the set of three front cam followers 8b-1 and the set of three rear cam followers 8b-2 in the optical axis direction is

determined so that the set of three front cam followers 8b-1 are respectively engaged in the set of three front cam grooves 11a-1 and so that the set of three rear cam followers 8b-2 are respectively engaged in the set of three rear cam grooves 11a-2. The diameter of each front cam follower 8b-1 and the diameter of each rear cam follower 8b-2 are the same.

【0043】

Figure 19 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is the retracted state as shown in Figure 7. When the zoom lens 71 is the retracted state, each front cam follower 8b-1 is positioned in the associated front cam groove 11a-1 in the vicinity of the third inflection point  $\alpha_n$  thereof while each rear cam follower 8b-2 is positioned in the associated rear cam groove 11a-2 in the vicinity of the third inflection point  $\alpha_n$  thereof. Since each front cam groove 11a-1 includes a portion thereof in the vicinity of the third inflection point  $\alpha_n$  while each rear cam groove 11a-2 includes a portion thereof in the vicinity of the third inflection point  $\alpha_n$ , each front cam follower 8b-1 and each rear cam follower 8b-2 are engaged in the associated front cam groove 11a-1 and the associated rear cam groove 11a-2, respectively.



【0044】

Rotating the cam ring 11 in the lens barrel  
advancing direction (upwards as viewed in Figure 19) in  
the retracted state shown in Figure 19 causes each front  
5 cam follower 8b-1 and each rear cam follower 8b-2 to be  
guided rearward in the optical axis direction to move on  
the third section  $\alpha 3$  toward the second inflection point  
 $\alpha m$  by the associated front cam groove 11a-1 and the  
associated rear cam groove 11a-2, respectively. In the  
10 middle of this movement of each cam follower 8b, each rear  
cam follower 8b-2 is disengaged from the associated rear  
cam groove 11a-2 through a rear end opening R3 thereof  
which opens on a rear end surface of the cam ring 11  
because each rear cam groove 11a-2 does not include  
15 adjoining portions of the second section  $\alpha 2$  and the third  
section  $\alpha 3$  on opposite sides of the second inflection  
point  $\alpha m$ . At this time, each front cam follower 8b-1  
remains engaged in the associated front cam groove 11a-1  
since each front cam groove 11a-1 includes a rear portion  
20 thereof in the optical axis direction which corresponds  
to the missing rear portion of each rear cam groove 11a-2  
in the optical axis direction. On or after each rear cam  
follower 8b-2 being disengaged from the associated rear  
cam groove 11a-2 through the rear end opening R3 thereof,  
25 the second lens group moving frame 8 moves in the optical

axis direction by rotation of the cam ring 11 only due to engagement of each front cam follower 8b-1 with the associated front cam groove 11a-1.

【0045】

5        Figure 20 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is in the state shown below the photographing lens axis Z1 in Figure 6 in which the zoom lens 71 is set at the wide-angle extremity. In  
10    this state shown below the photographing lens axis Z1 in Figure 6, each front cam follower 8b-1 is positioned in the second section  $\alpha 2$  slightly beyond the second inflection point  $\alpha m$ . Although each rear cam follower 8b-2 is currently disengaged from the associated rear cam  
15    groove 11a-2 through the rear end opening R3 thereof as described above, each rear cam follower 8b-2 remains positioned on the associated reference cam diagram  $\alpha$  because the associated front cam follower 8b-1 positioned in front of the rear cam follower 8b-2 remains  
20    engaged in the associated front cam groove 11a-1.

【0046】

Rotating the cam ring 11 in the lens barrel advancing direction (upward as viewed in Figure 20) in the state shown in Figure 20, in which the zoom lens 71  
25    is set at the wide-angle extremity, causes each front cam

follower 8b-1 to be guided forward in the optical axis direction to move on the second section  $\alpha 2$  toward the first section  $\alpha 1$  by the associated front cam groove 11a-1. With this forward movement of each front cam follower 8b-1, each rear cam follower 8b-2 which is currently disengaged from the associated rear cam groove 11a-2 moves on the second section  $\alpha 2$ , and shortly enters a rear end opening R2 formed on a rear end surface of the cam ring 11 to be re-engaged in the associated rear cam groove 11a-2. On or after this re-engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2, each front cam follower 8b-1 and each rear cam follower 8b-2 are guided by the associated front cam groove 11a-1 and the associated rear cam groove 11a-2, respectively. However, a shortly after the re-engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2, each front cam follower 8b-1 is disengaged from the associated front cam groove 11a-1 through the front end opening R1 because a front end portion of each front cam groove 11a-1 which lies on the associated reference cam diagram  $\alpha$  is missing. At this time, each rear cam follower 8b-2 remains engaged in the associated rear cam groove 11a-2 since each rear cam groove 11a-2 includes a front end portion thereof in the optical axis direction which corresponds to the

missing front end portion of each front cam groove 11a-1 in the optical axis direction. On or after each front cam follower 8b-1 being disengaged from the associated front cam groove 11a-1 through the front end opening R1 thereof, the second lens group moving frame 8 moves in the optical axis direction by rotation of the cam ring 11 only due to engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2.

【0047】

10 Figure 21 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is in the state shown above the photographing lens axis Z1 in Figure 6 in which the zoom lens 71 is set at the telephoto extremity. In  
15 this state shown above the photographing lens axis Z1 in Figure 6, each front cam follower 8b-1 is positioned in the second section  $\alpha 2$  in the vicinity of the first inflection point  $\alpha h$ . Although each front cam follower 8b-1 is currently disengaged from the associated front  
20 cam groove 11a-1 through the front end opening R1 thereof as described above, each front cam follower 8b-1 remains on the associated reference cam diagram  $\alpha$  because the associated rear cam follower 8b-2 positioned behind the front cam follower 8b-1 remains engaged in the associated  
25 rear cam groove 11a-2.

【0048】

Further rotating the cam ring 11 in the lens barrel  
advancing direction in the state shown in Figure 21, in  
which the zoom lens 71 is set at the telephoto extremity,  
5 causes each rear cam follower 8b-2 to enter the first  
section  $\alpha 1$  via the first inflection point  $\alpha h$  as shown  
in Figure 22. At this time, each front cam follower 8b-1  
has been disengaged from the associated front cam groove  
11a-1, and merely each rear cam follower 8b-2 is engaged  
10 in a front end portion (the first section  $\alpha 1$ ) of the  
associated rear cam groove 11a-2 which extends in the  
optical axis direction, so that the second lens group  
moving frame 8 can be removed from the cam ring 11 from  
the front thereof in the optical axis direction to remove  
15 each rear cam follower 8b-2 from the associated rear cam  
groove 11a-2 via the front end opening R4. Accordingly,  
Figure 22 shows a state where the cam ring 11 and the  
second lens group moving frame 8 are put together or  
removed from each other.

20 【0049】

Figures 23 through 26 show the relationship between  
the cam ring 11 and the second lens group moving frame  
8 in the retracted state, the wide-angle extremity state,  
the telephoto extremity state and the disassembled  
25 state, respectively, wherein the reference cam diagram

$\alpha$  are not illustrated while the second linear guide ring

10 is additionally illustrated in the drawings.

【0050】

As described above, each pair of cam grooves having  
5 the same reference cam diagram, i.e., each front cam  
groove 11a-1 and the associated rear cam groove 11a-2 are  
formed at different points in the optical axis direction  
on the cam ring 11; moreover, each front cam groove 11a-1  
and the associated rear cam groove 11a-2 are formed so  
10 that one end of the front cam groove 11a-1 opens on a front  
end surface of the cam ring 11 without the front cam  
groove 11a-1 including the entire part of the associated  
reference cam diagram  $\alpha$  and so that one end of the rear  
cam groove 11a-2 opens on a rear end surface of the cam  
15 ring 11 without the rear cam groove 11a-2 including the  
entire part of the associated reference cam diagram  $\alpha$   
; and furthermore, one of the front cam groove 11a-1 and  
the rear cam groove 11a-2 is complemented by the other  
to include the entire part of one reference cam diagram  
20  $\alpha$ . In addition, only each rear cam follower 8b-2 is  
engaged in the associated rear cam groove 11a-2 when the  
second lens group moving frame 8 is positioned at a front  
limit for the axial movement thereof with respect to the  
cam ring 11 (which corresponds to the state shown above  
25 the photographing lens axis Z1 in Figure 6 in which the

zoom lens 71 is set at the telephoto extremity), while  
only each front cam follower 8b-1 is engaged in the  
associated front cam groove 11a-1 when the second lens  
group moving frame 8 is positioned at a rear limit for  
5 the axial movement thereof with respect to the cam ring  
11 (which corresponds to a state shown below the  
photographing lens axis Z1 in Figure 6 in which the zoom  
lens 71 is set at the wide-angle extremity). With this  
structure, a sufficient range of movement of the second  
10 lens group moving frame 8 in the optical axis direction  
which is greater than the range of movement of the cam  
ring 11 in the optical axis direction is achieved.  
Namely, the length of the cam ring 11 in the optical axis  
direction can be reduced without sacrificing the range  
15 of movement of the second lens group moving frame 8, which  
supports the second lens group LG2, in the optical axis  
direction.

【0051】

The present embodiment of the barrel-advancing cam  
20 mechanism including the cam ring 11 has the following  
feature. In general, the amount of movement of each cam  
follower per unit of rotation of the cam ring decreases  
to thereby make it possible to move the driven member with  
a higher degree of positioning accuracy by rotation of  
25 the cam ring as the degree of inclination of each cam

groove on the cam ring relative to the rotational direction of the cam ring becomes small, i.e., as the direction of extension of each cam groove becomes close to a circumferential direction of the cam ring. In addition, the degree of resistance to the cam ring when it rotates becomes smaller to thereby make the driving torque for rotating the cam ring smaller as the degree of inclination of each cam groove on the cam ring relative to the rotational direction of the cam ring becomes small. A reduction of the driving torque results in an increase in durability of elements of the cam mechanism and a decrease in power consumption of the motor for driving the cam ring, and makes it possible to adopt a small motor for driving the cam ring to downsize the lens barrel. Although it is known that the actual contours of the cam grooves are determined in consideration of various factors such as the effective area of an outer or inner peripheral surface of the cam ring and the maximum angle of rotation of the cam ring, it is generally the case that there are the above described tendencies as for the cam grooves.

【0052】

It can be said that the cam ring 11 is provided, at regular intervals in a circumferential direction of the cam ring 11, with three pairs of cam grooves 11a for



guiding the second lens group LG2 if each front cam groove 11a-1 and the rear cam groove 11a-2 positioned therebehind in the optical axis direction are regarded as a pair. As for the reference cam diagrams  $\alpha$  of the plurality of cam grooves 11a, provided only three of the reference cam diagrams  $\alpha$  are to be arranged on an inner peripheral surface of the cam ring 11 along a line thereon extending in a circumferential direction of the cam ring 11, the three reference cam diagrams  $\alpha$  will not interfere with one another on the inner peripheral surface of the cam ring 11 though each reference cam diagram  $\alpha$  has an undulating shape. However, in the present embodiment of the zoom lens, in order to shorten the length of the cam ring 11 in the optical axis direction to thereby minimize the length of the zoom lens 71, six reference cam diagrams  $\alpha$  need to be arranged on the inner peripheral surface of the cam ring 11 in total because the set of three front cam grooves 11a-1 and the corresponding set of three rear cam grooves (three discontinuous rear cam grooves) 11a-2, six cam grooves in total, need to be formed separately on front and rear portions on the inner peripheral surface of the cam ring 11 in the optical axis direction, respectively. Although each of the six cam grooves 11a-1 and 11a-2 is shorter than the reference cam diagram  $\alpha$ , it is generally the case that the space for

the cam grooves 11a-1 and 11a-2 on the cam ring 11 becomes tighter as the number of the cam grooves is great. Therefore, if the number of the cam grooves is great, it is difficult to form the cam grooves on the cam ring without making the cam grooves interfering with each other. To prevent this problem from occurring, it has been conventionally practiced to increase the degree of inclination of each cam groove relative to the rotational direction of the cam ring (i.e., to make the direction of extension of each cam groove close to a circumferential direction of the cam ring) or to increase the diameter of the cam ring to enlarge the area of a peripheral surface of the cam ring on which the cam grooves are formed. However, the former is not preferable in terms of the attainment of a high degree of positioning accuracy in driving a driven member driven by the cam ring and also a saving in the driving torque for rotating the cam ring, and the latter is not preferable either because the zoom lens will be upsized.

20       【0053】

In contrast to such conventional practices, according to the present embodiment of the zoom lens, the inventor of the present invention has found the fact that a substantial performance characteristics of the cam mechanism is maintained even if each front cam groove

11a-1 intersects one of the set of three rear cam grooves  
11a-2, as long as the reference cam diagrams  $\alpha$  of the  
six cam grooves 11a (11a-1 and 11a-2) are the same while  
one cam follower of each pair of cam followers (each front  
5 cam follower 8b-1 and the associated rear cam follower  
8b-2) remains engaged in the associated cam groove 11a-1  
or 11a-2 at the moment at which the other cam follower  
8b-1 or 8b-2 passes through a point of intersection  
between the front cam groove 11a-1 and the rear cam groove  
10 11a-2. On the basis of this fact, each front cam groove  
11a-1 and adjacent one of the set of three rear cam  
grooves 11a-2, which are adjacent to each other in a  
circumferential direction of the cam ring 11, are formed  
to intersect each other intentionally without changing  
15 the shape of each reference cam diagram  $\alpha$  and without  
increasing the diameter of the cam ring 11. More  
specifically, if the three pairs of cam grooves 11a are  
respectively treated as a first pair of cam grooves G1,  
a second pair of cam grooves G2 and a third pair of cam  
20 grooves G3 as shown in Figure 14, the front cam groove  
11a-1 of the first pair G1 and the rear cam groove 11a-2  
of the second pair G2, which are adjacent to each other  
in a circumferential direction of the cam ring 11,  
intersect each other; the first cam groove 11a-1 of the  
25 second pair G2 and the rear cam groove 11a-2 of the third

pair G3, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other, and the front cam groove 11a-1 of the third pair G3 and the rear cam groove 11a-2 of the first pair  
5 G1, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other.

【0054】

To make one cam follower of each pair of cam followers remain properly engaged in the associated cam  
10 groove 11a-1 or 11a-2 at the moment at which the other cam follower passes through the point of intersection between the front cam groove 11a-1 and the rear cam groove 11a-2, the front cam groove 11a-1 and the rear cam groove 11a-2 of each pair of the first through third pairs  
15 of cam grooves G1, G2 and G3 are formed not only at different axial positions in the optical axis direction but also at different circumferential positions in a circumferential direction of the cam ring 11. The positional difference in a circumferential direction of  
20 the cam ring 11 between the front cam groove 11a-1 and the rear cam groove 11a-2 of each pair of the first through third pairs of cam grooves G1, G2 and G3 is indicated by " $\beta$ " in Figure 14. This positional difference  $\beta$  changes the point of intersection between  
25 the front cam groove 11a-1 and the rear cam groove 11a-2

in a circumferential direction of the cam ring 11.

Consequently, in each pair of the first through third pairs of cam grooves G1, G2 and G3, the point of intersection is positioned in the vicinity of the second inflection point  $\alpha_m$  on the third section  $\alpha_3$  of the front cam groove 11a-1, and also in the vicinity of the front end opening R4 (in the vicinity of the first inflection point  $\alpha_h$ ) at the front end of the first section  $\alpha_1$ .

【0055】

10 As can be understood from the above descriptions, at the moment at which the set of three front cam followers 8b-1 pass through the points of intersection in the set of three front cam grooves 11a-1, the set of three rear cam followers 8b-2 remain engaged in the set  
15 of three rear cam grooves 11a-2 so that the set of three front cam followers 8b-1 can pass through the points of intersection without being disengaged from the set of three front cam grooves 11a-1, respectively (see Figure 28), by forming the set of three front cam grooves 11a-1  
20 and the corresponding set of three rear cam grooves 11a-2 in the above described manner. Although each front cam groove 11a-1 has the point of intersection therein between the zooming section and the lens-barrel retracting section, i.e. in the lens-barrel operating  
25 section, the lens barrel 71 can surely be advanced and

retracted with the cam ring 11 regardless of the  
existence of a section of each front cam groove 11a-1  
which includes the point of intersection therein.  
Although each front cam follower 8b-1 is already  
5 disengaged from the associated front cam groove 11a-1  
when each rear cam follower 8b-2 reaches the point of  
intersection in the rear cam groove 11a-2 as shown in  
Figures 21 and 25, this point of intersection is  
positioned in the lens-barrel assembling/disassembling  
10 section, i.e., out of the lens-barrel operating section,  
so that each rear cam follower 8b-2 is not in a state where  
it receives a torque from the cam ring 11. Accordingly,  
as for the set of three rear cam grooves 11a-2, a  
possibility of each rear cam follower 8b-2 being  
15 disengaged from the associated rear cam groove 11a-2 at  
the point of intersection therein does not have to be  
taken into consideration when the zoom lens 71 is in the  
ready-to-photograph state.

【0056】

20 The point of intersection in each front cam groove  
11a-1 is in a section thereof through which the  
associated front cam follower 8b-1 passes between the  
retracted state of the zoom lens and the wide-angle  
extremity state of the zoom lens, while the point of  
25 intersection in each rear cam groove 11a-2 is in the

lens-barrel assembling/disassembling section as  
described above. Therefore, either each front cam  
groove 11a-1 or each rear cam groove 11a-2 does not have  
the point of intersection therein in the zooming range  
5 between the wide-angle extremity and the telephoto  
extremity. This makes it possible to insure a high  
degree of positioning accuracy in driving the second lens  
group LG2 during a zooming operation of the zoom lens 71  
regardless of the existence of the point of intersection  
10 between cam grooves.

【0057】

Namely, the timing of engagement or disengagement  
of each cam follower in or from the associated cam groove  
can be varied by adjusting the positional difference in  
15 a circumferential direction of the cam ring 11 between  
the front and rear cam grooves 11a-1 and 11a-2, the  
reference cam diagrams  $\alpha$  of which are the same.  
Moreover, the point of intersection between two cam  
grooves (11a-1 and 11a-2) can be positioned in an  
20 appropriate section therein which does not affect any  
adverse effect on a zooming operation by adjusting the  
aforementioned positional difference.

【0058】

As can be understood from the above descriptions,  
25 in the present embodiment of the zoom lens, each front

cam groove 11a-1 and each rear cam groove 11a-2 are  
successfully arranged on the inner peripheral surface of  
the cam ring 11 in a space-saving fashion without  
deteriorating the positioning accuracy in driving the  
5 second lens group LG2 by making each front cam groove  
11a-1 and adjacent one of the set of three rear cam  
grooves 11a-2, which are adjacent to each other in a  
circumferential direction of the cam ring 11, intersect  
each other intentionally and further by forming each  
10 front cam groove 11a-1 and the associated rear cam groove  
11a-2 not only at different axial positions in the  
optical axis direction but also at different  
circumferential positions in a circumferential  
direction of the cam ring 11. Accordingly, not only the  
15 length of the cam ring 11 in the optical axis direction  
but also the diameter of the cam ring 11 can be reduced.

【0059】

Although the plurality of cam grooves 11a (the set  
of three front cam grooves 11a-1 and the set of three rear  
20 cam grooves 11a-2) are provided as three groups of cam  
grooves which are formed at different circumferential  
positions in a circumferential direction of the cam ring  
while the plurality of cam followers 8b (the set of three  
front cam followers 8b-1 and the set of set of three rear  
25 cam followers 8b-2) are also provided as three groups of



cam followers which are formed at different  
circumferential positions in a circumferential  
direction of the second lens group moving frame 8 in the  
above illustrated embodiment, the number of groups of cam  
5 grooves formed on the cam ring 11 and the corresponding  
number of groups of cam followers formed on the second  
lens group moving frame 8 are optional.

【0060】

Although the number of cam grooves (11a-1 and 11a-2)  
10 included in each group of the three groups of cam grooves  
and formed at different positions along a rotational axis  
of the cam ring 11 is two while the number of cam followers  
(8b-1 and 8b-2) included in each group of the three groups  
of cam followers and formed at different positions along  
15 the rotational axis of the cam ring 11 is also two in the  
above illustrated embodiment, each of the former number  
and the latter number can be more than three. In the case  
where each of the former number and the latter number is  
more than three, not only each of the front and rear cam  
20 grooves is formed not to include a part of the entire  
portion of the associated reference cam diagram but also  
the middle cam groove is formed not to include a part of  
the entire portion of the associated reference cam  
diagram.

25           【0061】

Although each front cam groove 11a-1 is formed as  
a short cam groove excluding a front part of the entire  
portion of the associated reference cam diagram  $\alpha$  while  
each rear cam groove 11a-2 is formed as a short cam groove  
5 excluding a rear part of the entire portion of the  
associated reference cam diagram  $\alpha$ , the position of each  
end opening of either of the cam grooves 11a-1 and 11a-2  
is optional. For instance, each rear cam groove 11a-2  
does not need to be provided with the front end opening  
10 G4 if the cam ring does not have to be made in  
consideration of the workability of assembling and  
disassembling the zoom lens 71.

【0062】

Although the above illustrated embodiment relates  
15 to a zoom lens, the present invention can also be applied  
to various barrel-advancing cam mechanisms of any  
technical fields other than the technical field of the  
zoom lenses.

【0063】

20 【Effects of the Invention】

As can be understood from the foregoing, according  
to the barrel-advancing cam mechanism to which the  
present invention is applied, a cam ring can be  
miniaturized while the necessary moving amounts for  
25 movable lens groups and any other linearly moving

elements can be secured.

【BRIEF DESCRIPTION OF THE DRAWING】

Figure 1 is an exploded perspective view of an embodiment of a zoom lens having a barrel-advancing cam mechanism according to the present invention;

Figure 2 is an exploded perspective view of a structure supporting a first lens group of the zoom lens;

Figure 3 is an exploded perspective view of a structure supporting a second lens group of the zoom lens;

Figure 4 is an exploded perspective view of a barrel-advancing structure from a stationary barrel to a cam ring;

Figure 5 is a perspective view of the zoom lens shown in Figure 1, showing a completed state thereof to which a zoom motor and a viewfinder unit are fixed;

Figure 6 is a longitudinal cross sectional view of a camera incorporating the zoom lens shown in Figure 1, showing a state of the zoom lens at telephoto extremity and a state of the zoom lens at wide-angle extremity;

Figure 7 is a longitudinal cross sectional view of the camera shown in Figure 6 in the retracted state of the zoom lens;

Figure 8 is a plan view of the stationary barrel;

Figure 9 is a plan view of a helicoid ring;

Figure 10 is a plan view of the helicoid ring,  
showing a structure of the inner peripheral surface  
thereof by broken lines;

Figure 11 is a plan view of a third external barrel;

5 Figure 12 is a plan view of a linear guide ring;

Figure 13 is a plan view of the cam ring;

Figure 14 is a plan view of the cam ring, showing  
a structure of the inner peripheral surface thereof by  
broken lines;

10 Figure 15 is a plan view of a second linear guide  
ring;

Figure 16 is a plan view of a second lens group  
moving frame;

Figure 17 is a plan view of a second external barrel;

15 Figure 18 is a plan view of a first external barrel;

Figure 19 is a plan view of the cam ring and the  
second lens group moving frame, showing the relationship  
therebetween in the retracted state of the zoom lens;

Figure 20 is a plan view of the cam ring and the  
20 second lens group moving frame, showing the relationship  
therebetween at the wide-angle extremity of the zoom  
lens;

Figure 21 is a plan view of the cam ring and the  
second lens group moving frame, showing the relationship  
25 therebetween at the telephoto extremity of the zoom lens;

Figure 22 is a plan view of the cam ring and the second lens group moving frame, showing the relationship therebetween in a state where the zoom lens can be disassembled;

5        Figure 23 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong in the retracted state of the zoom lens;

10       Figure 24 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong at the wide-angle extremity of the zoom lens;

15       Figure 25 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong at the telephoto extremity of the zoom lens;

20       Figure 26 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong in a state where the zoom lens can be disassembled;

25       Figure 27 is a plan view of the cam ring, showing the positions of cam followers for the second lens group in cam grooves for guiding the second lens group when the zoom lens is in the retracted position, the wide-angle extremity position and the telephoto extremity position;

and

Figure 28 is plan view of the cam ring, showing a state where a set of front cam followers pass through the points of intersection between a set of front cam grooves and a set of rear cam grooves of the cam ring.

【DESCRIPTIONS OF THE NUMERALS】

$\alpha$  reference cam diagrams of cam grooves for guiding the second lens group

$\beta$  positional difference in a circumferential direction of a cam ring between front cam groove and rear cam groove of the cam grooves for guiding the second lens group

LG1 first lens group

LG2 second lens group

LG3 third lens group

15 LG4 fourth lens group

S shutter

A diaphragm

Z0 lens barrel axis

Z1 photographing optical axis

20 Z2 optical axis of the second lens group

Z3 optical axis of an objective optical system of a viewfinder

1 first lens frame

6 second lens frame

25 8 second lens group moving frame (linearly movable

ring)

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- 8a linear guide groove
- 8b cam followers for the second lens group (cam follower group)
- 5 8b-1 front cam followers
- 8b-2 rear cam followers
- 10 second linear guide ring
- 10a bifurcated projections
- 10b ring portion
- 10 10c linear guide keys
- 11 cam ring
- 11a cam grooves for guiding the second lens group (cam groove group)
- 11a-1 front cam grooves
- 15 11a-2 rear cam grooves
- 11b cam grooves for guiding the first lens group
- 11c circumferential groove
- 12 first external barrel
- 13 second external barrel
- 20 14 linear guide ring
- 15 third external barrel
- 17 roller-biasing spring
- 18 helicoid ring
- 21 CCD holder
- 25 22 stationary barrel

28 zoom gear

---

31 rollers for the first lens group

32 followers of the cam ring

33 pivot shaft for the second lens group

5 51 AF lens frame

60 solid-state image pick-up device (CCD)

70 digital camera

71 zoom lens

72 camera body

10 76 shutter unit

80 viewfinder unit

150 zoom motor

160 AF motor



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[TITLE OF THE DOCUMENT]      ABSTRACT  
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[ABSTRACT]

[OBJECTIVE]

It is an object of the present invention to provide  
5 a barrel-advancing cam mechanism, having a cam ring and  
used in a zoom lens, wherein the cam ring is miniaturized  
without sacrificing the range of movement of one or more  
movable lens group.

[CONSTITUTION]

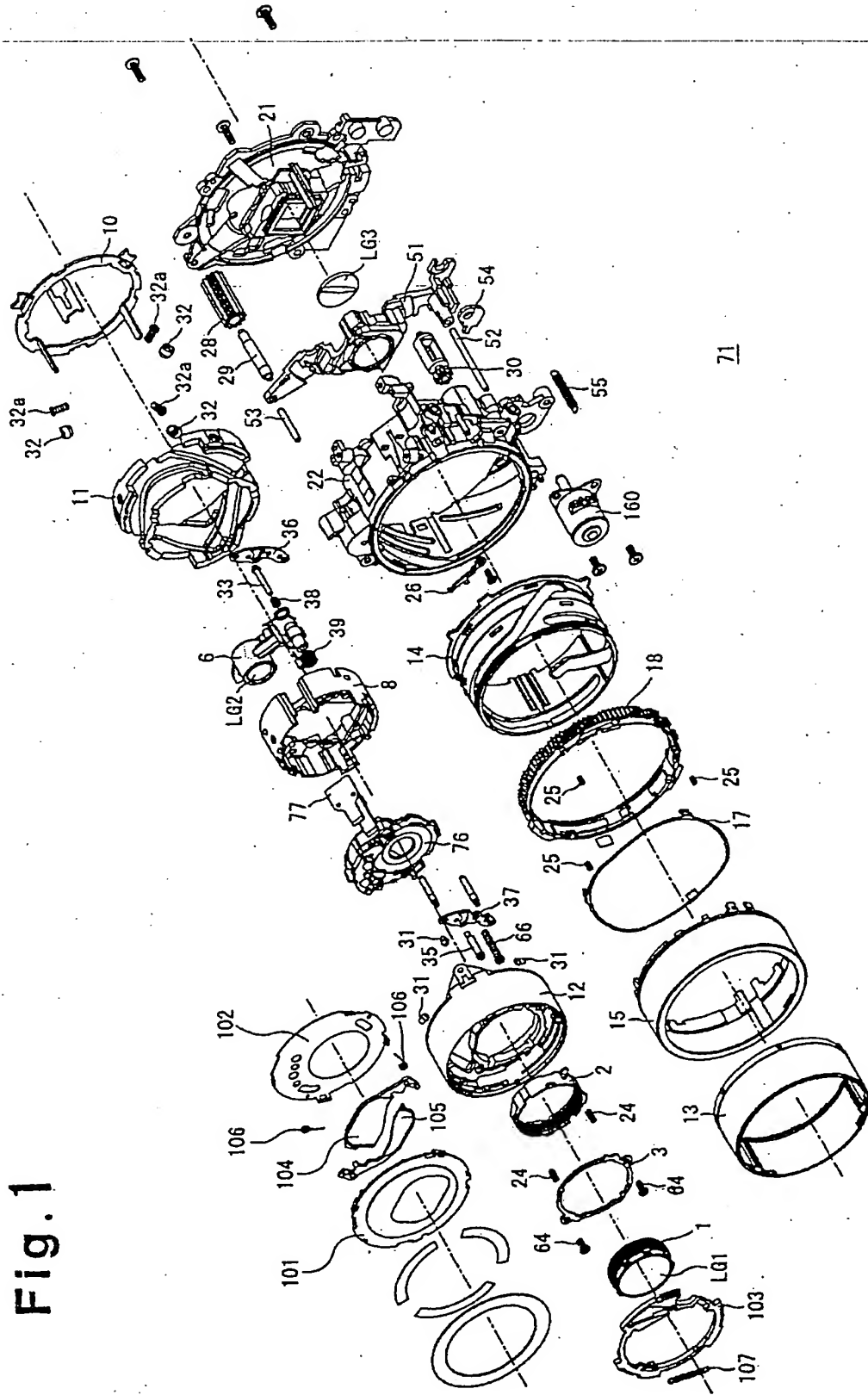
10      A barrel-advancing cam mechanism of a zoom lens  
which includes: a cam ring having a plurality of cam  
grooves formed at different positions at least in the  
optical axis direction and which trace substantially a  
same reference cam diagram, wherein all cam grooves of  
15 the plurality of cam grooves are partial cam grooves each  
having at least one end opening at at least one of  
opposite ends of the cam ring so as not to include an  
entire portion of the reference cam diagram. The  
plurality of cam followers are formed on a linearly  
20 movable ring at different positions at least in the  
optical axis direction and are respectively engageable  
in the plurality of cam grooves. At least one of the  
plurality of cam followers remains engaged in a  
corresponding the cam groove while at least one of the  
25 other of the plurality of cam followers comes out of the

end opening and is disengaged therefrom, when the linearly movable ring moves to at least one of opposite limits for movement thereof in the optical axis direction.

5   【SELECTED FIGURE】

Figure 20

Fig. 1



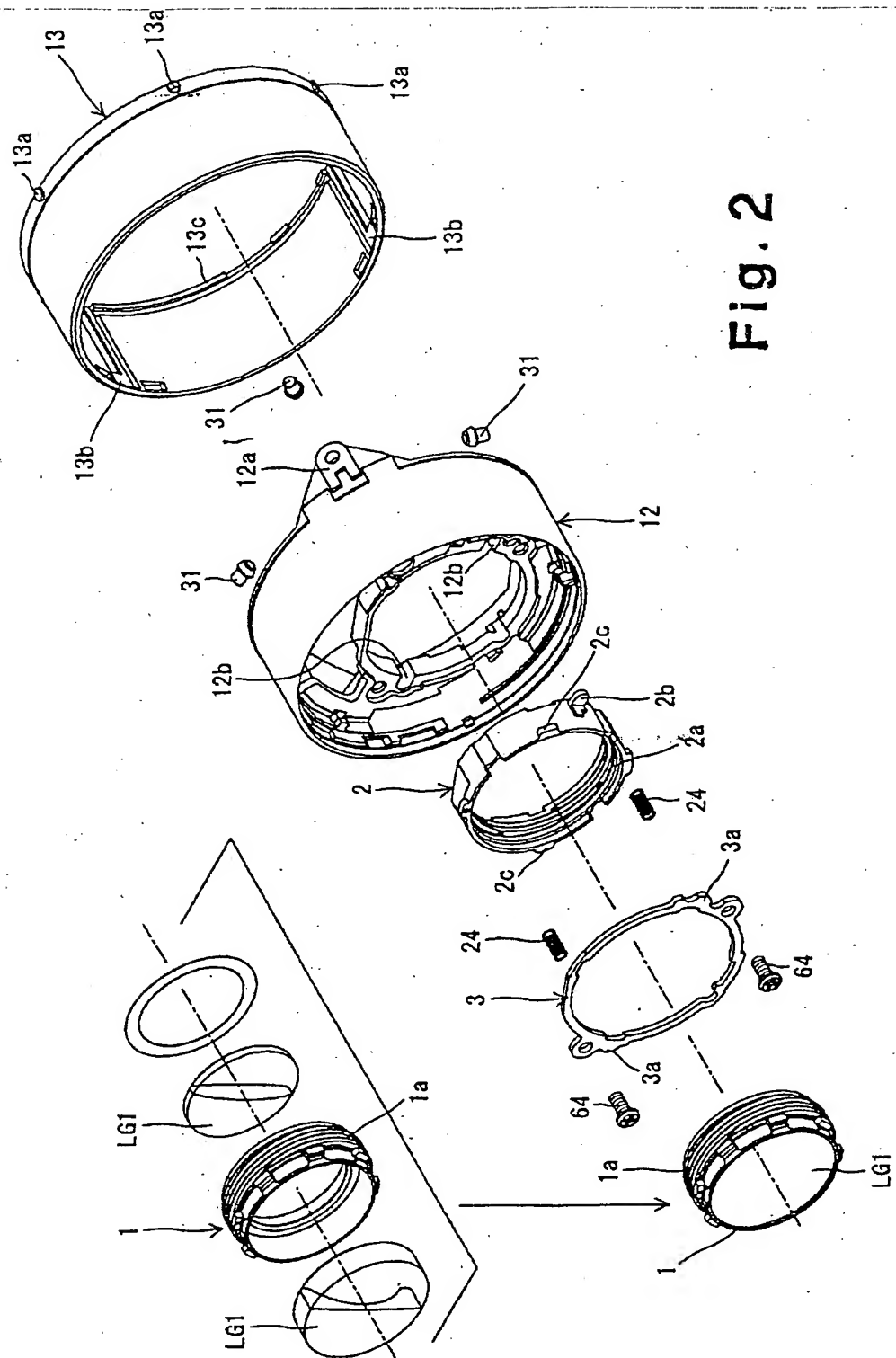


Fig. 2

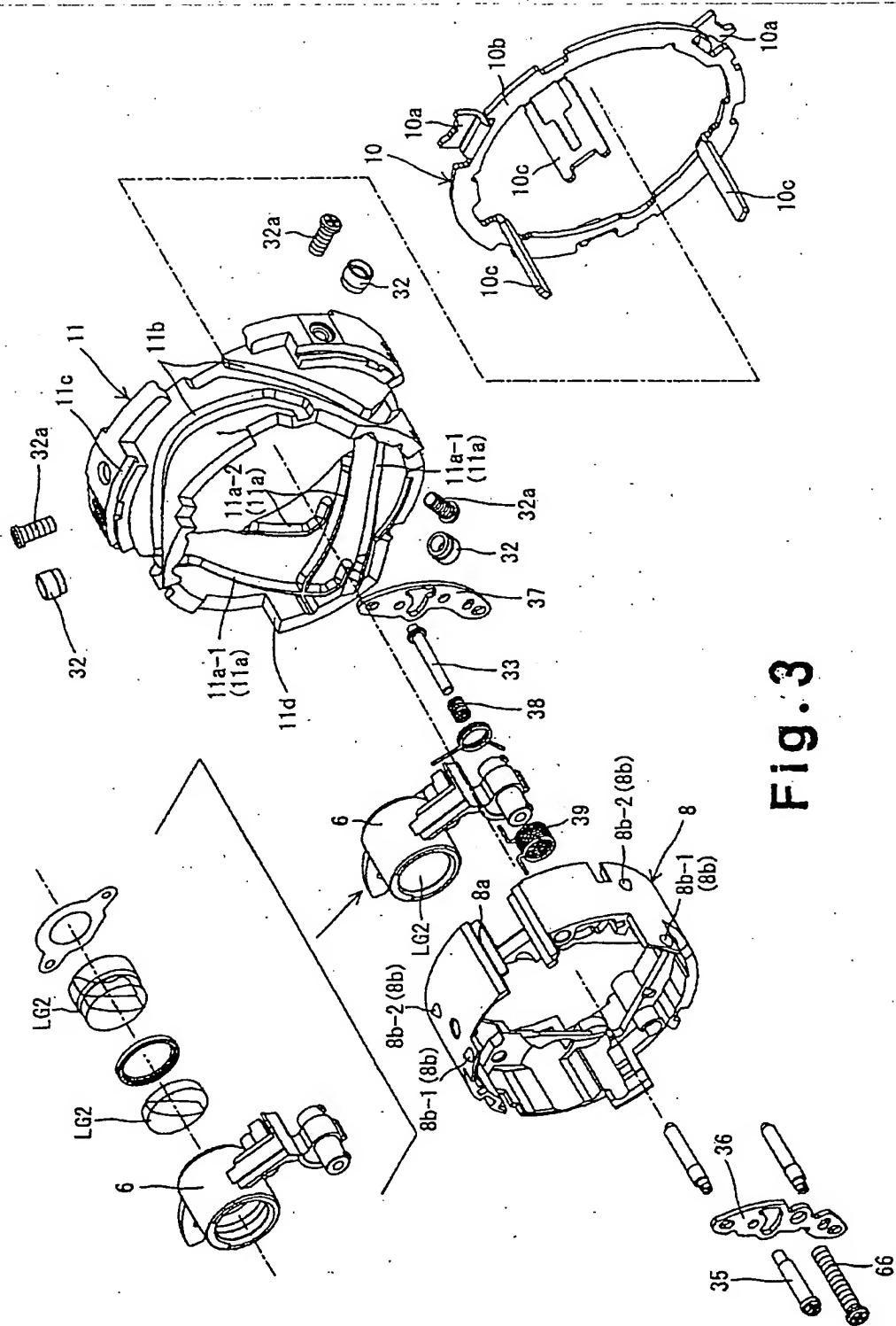


Fig. 3

Fig. 4

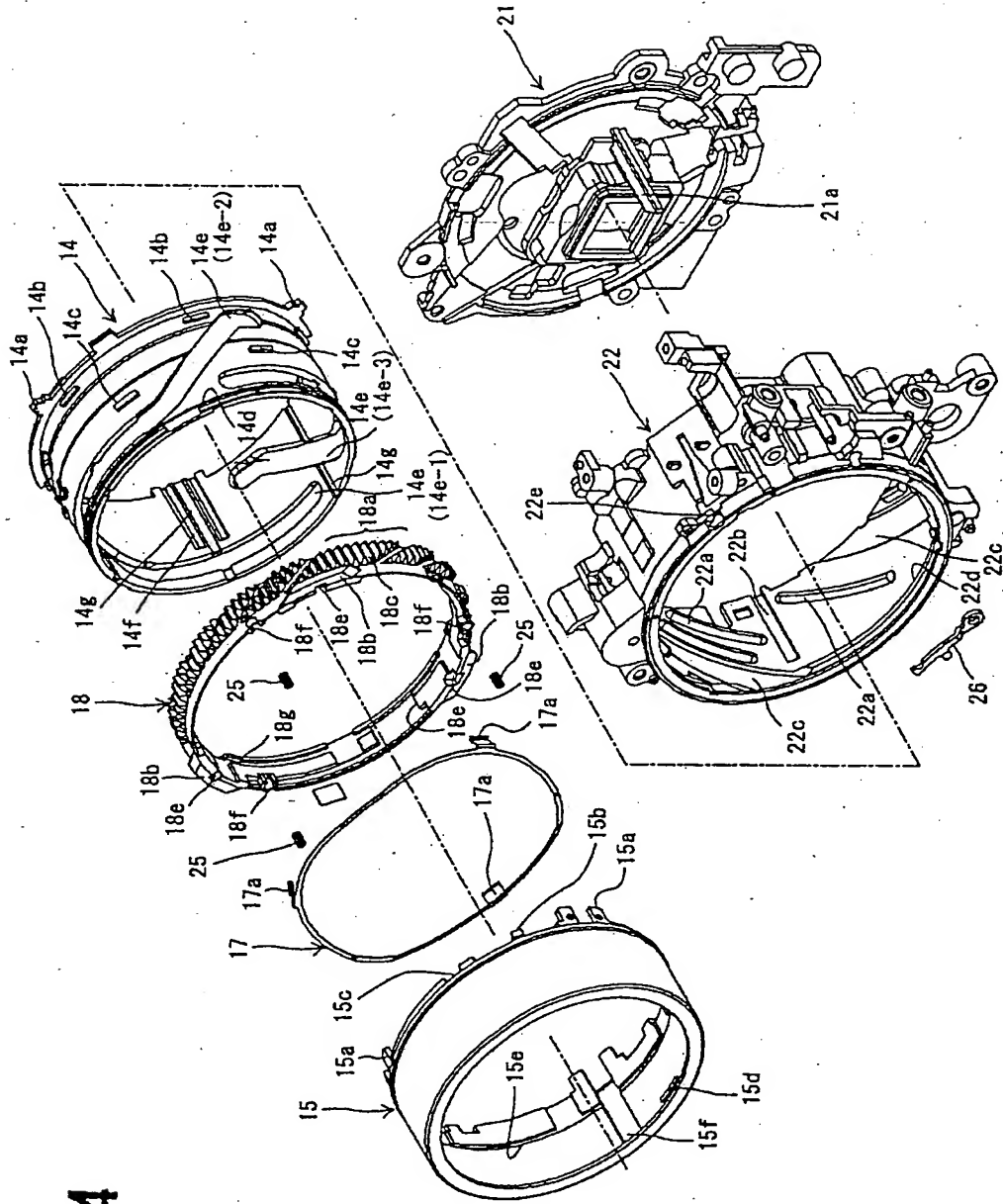


Fig.5

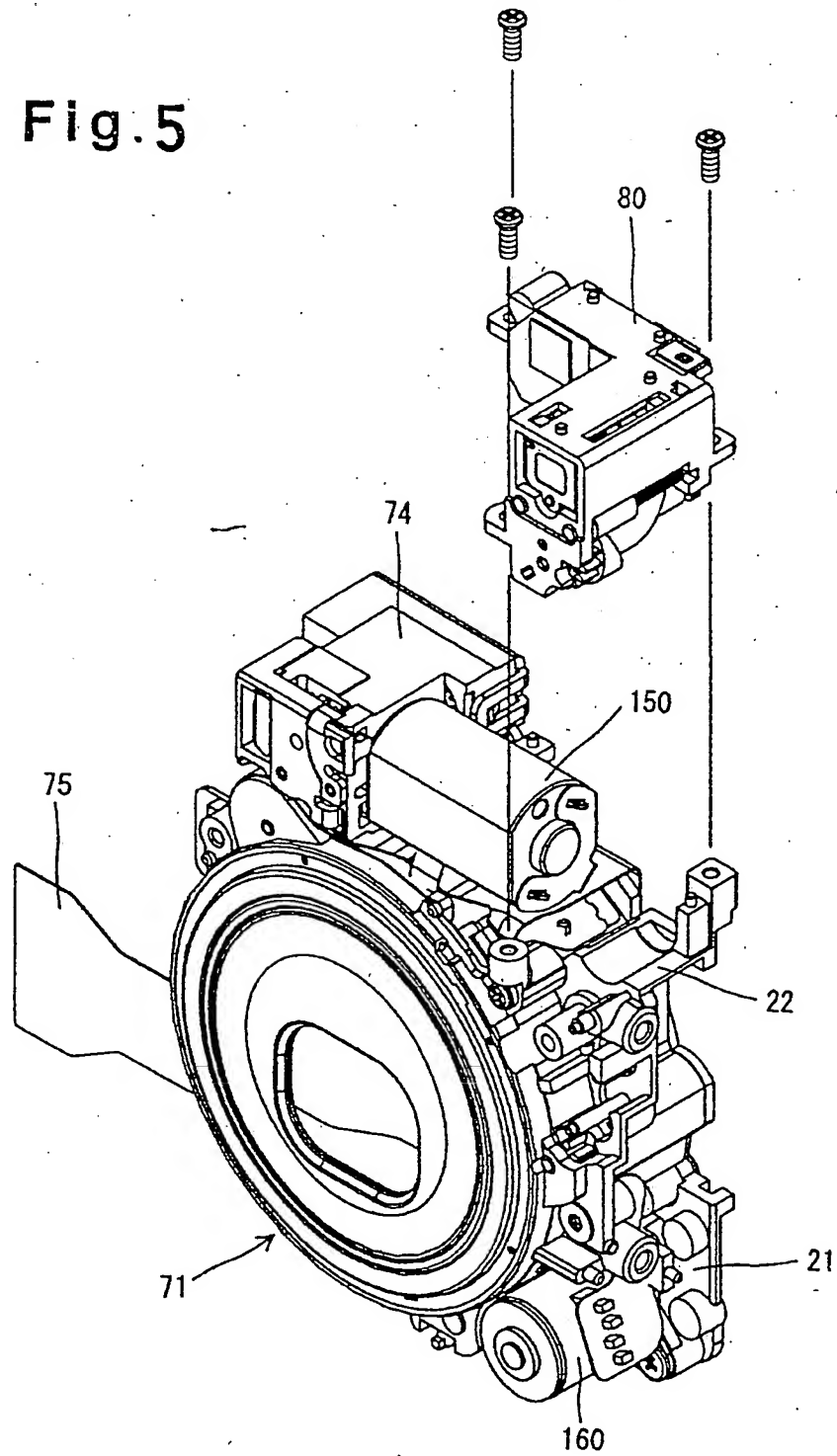
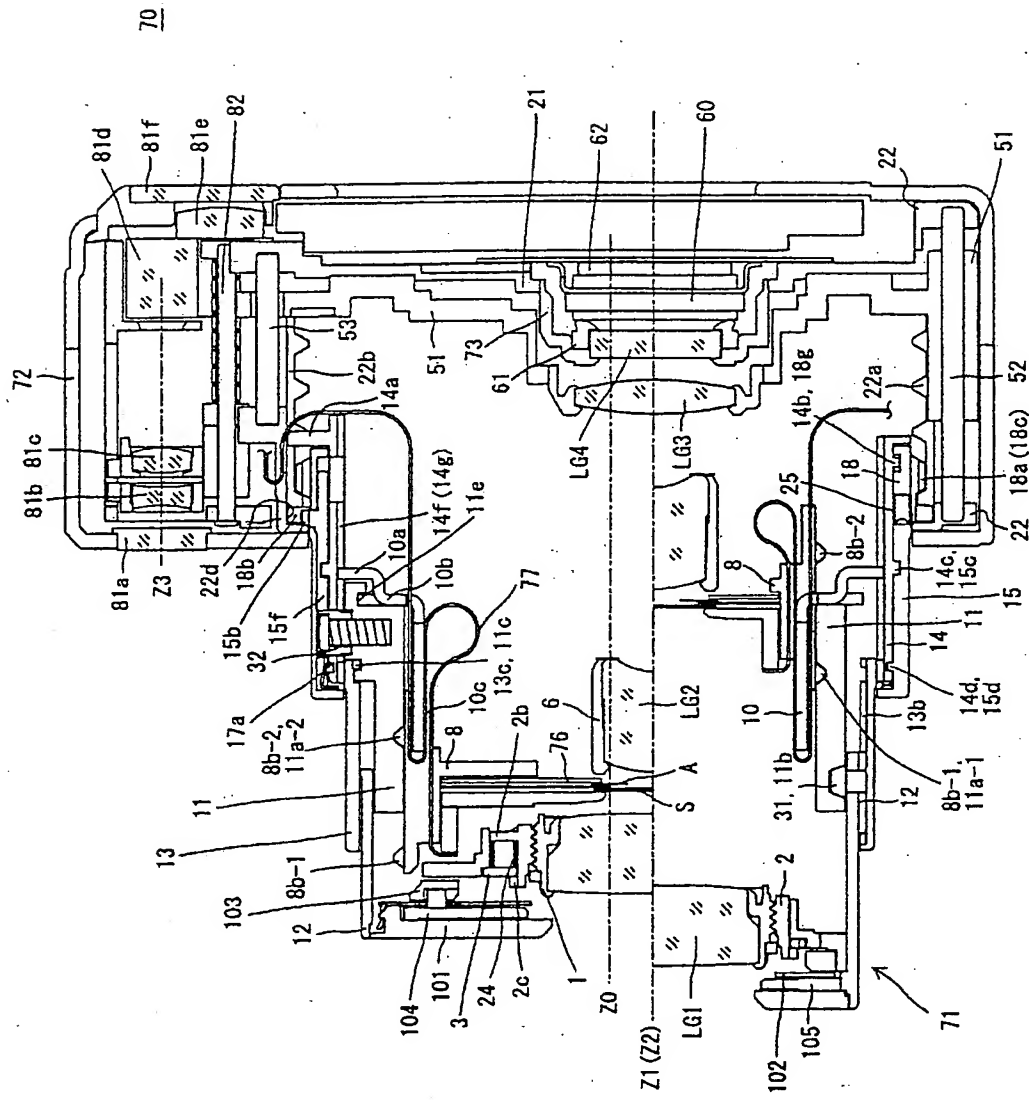
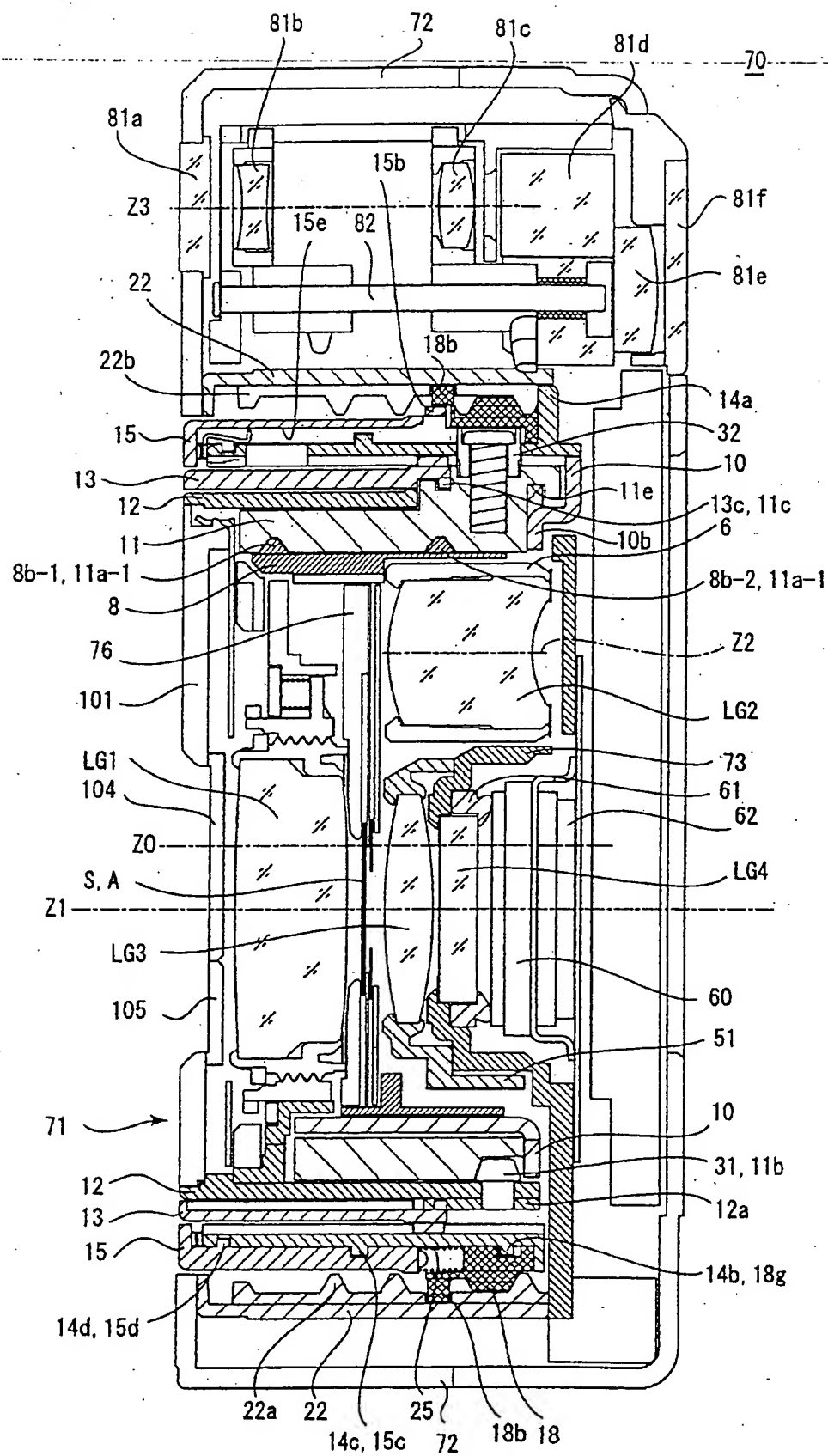


Fig. 6





**Fig. 7**



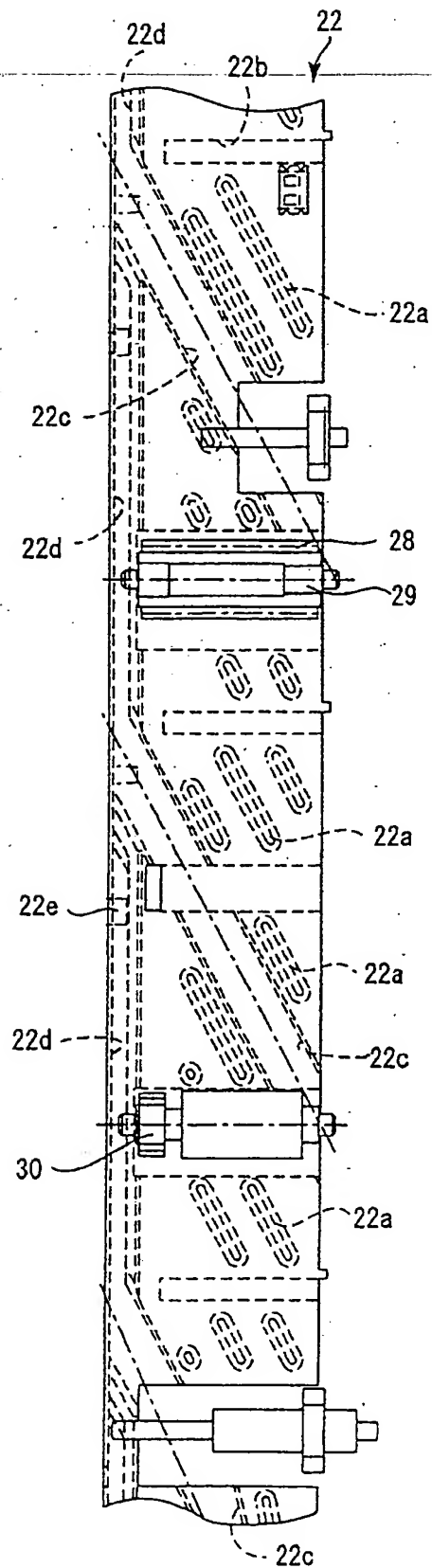
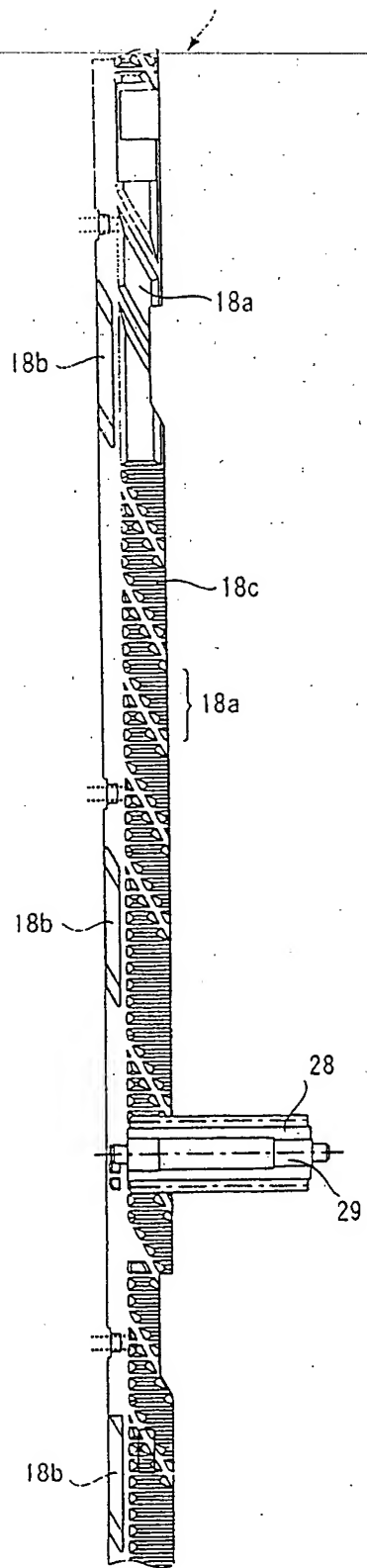
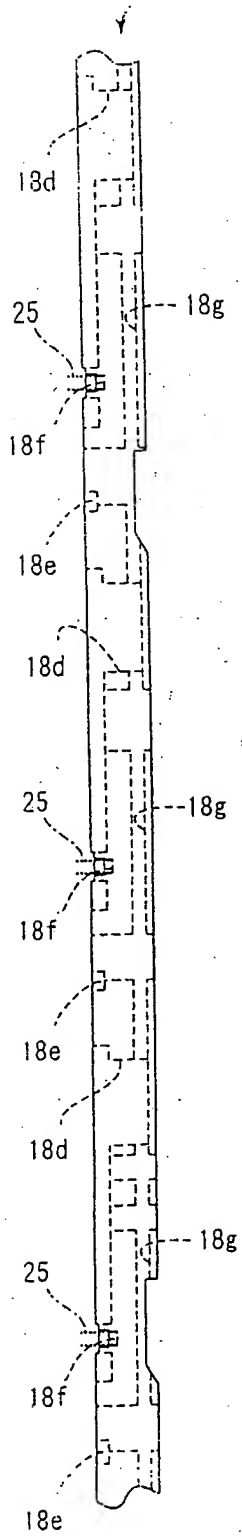


Fig. 8



F i g . 9

18



F i g . 1 0

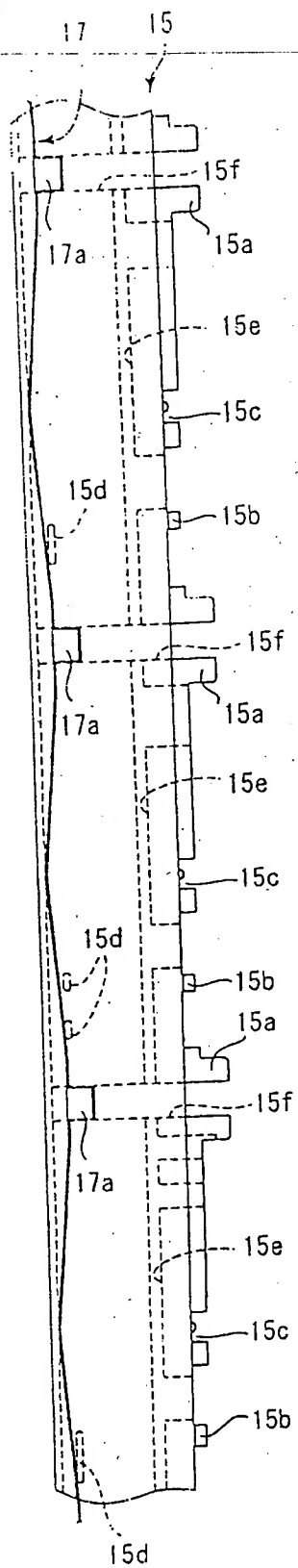


Fig. 11

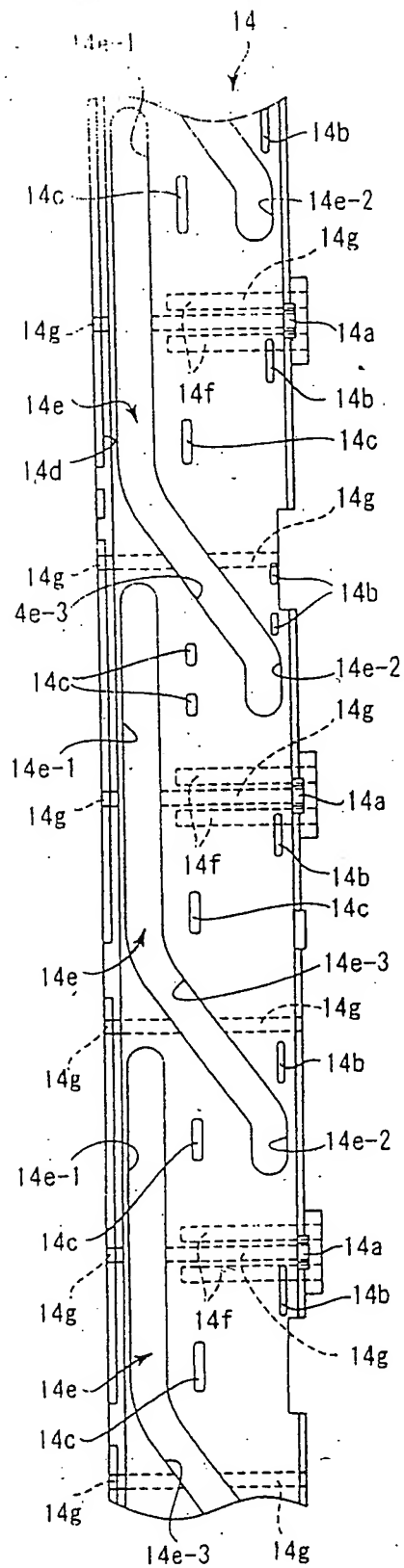


Fig. 12

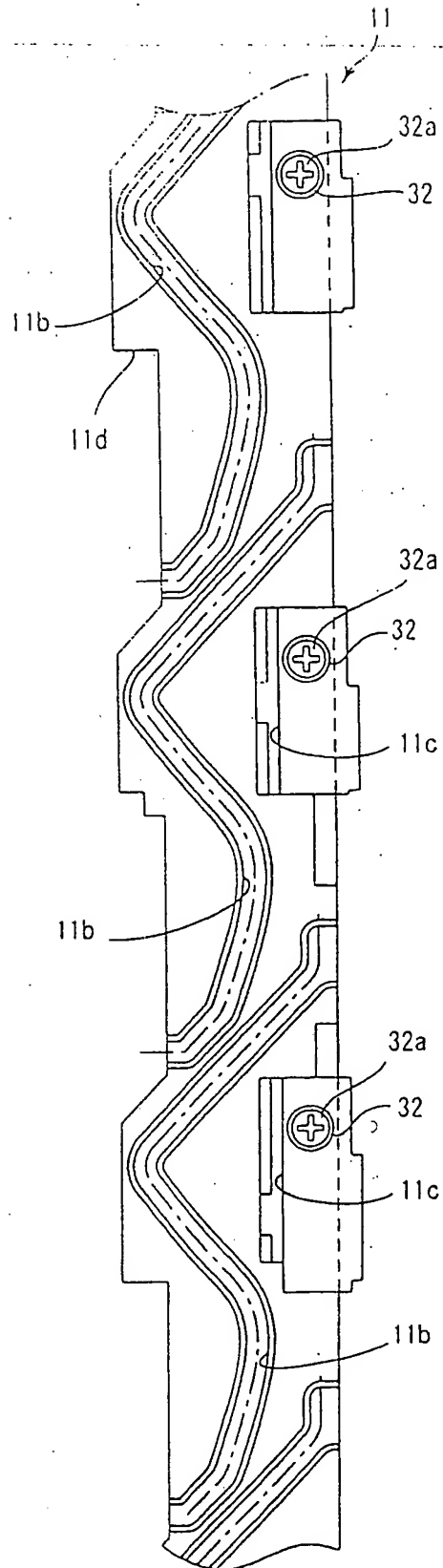


Fig. 13

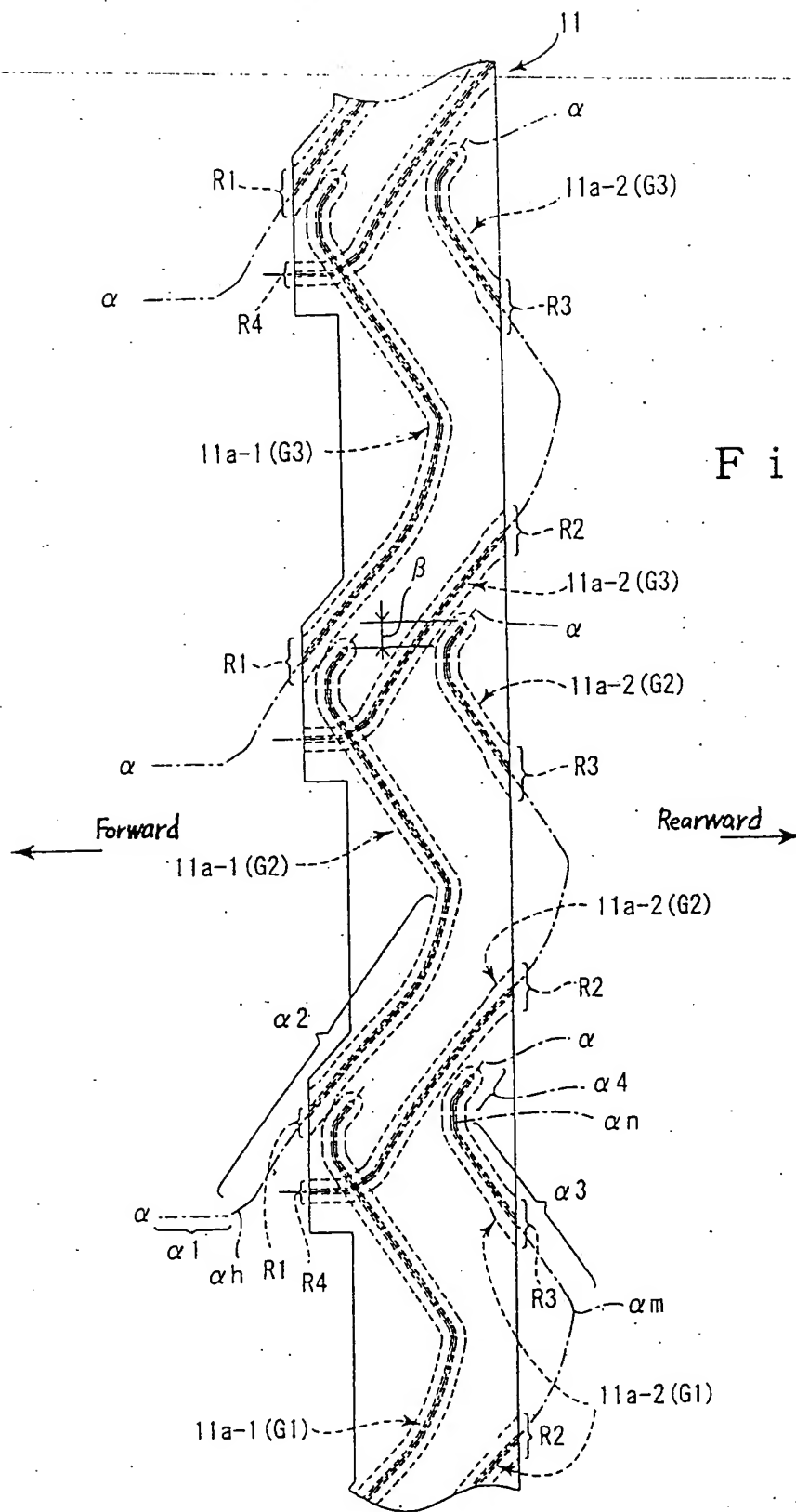


Fig. 14



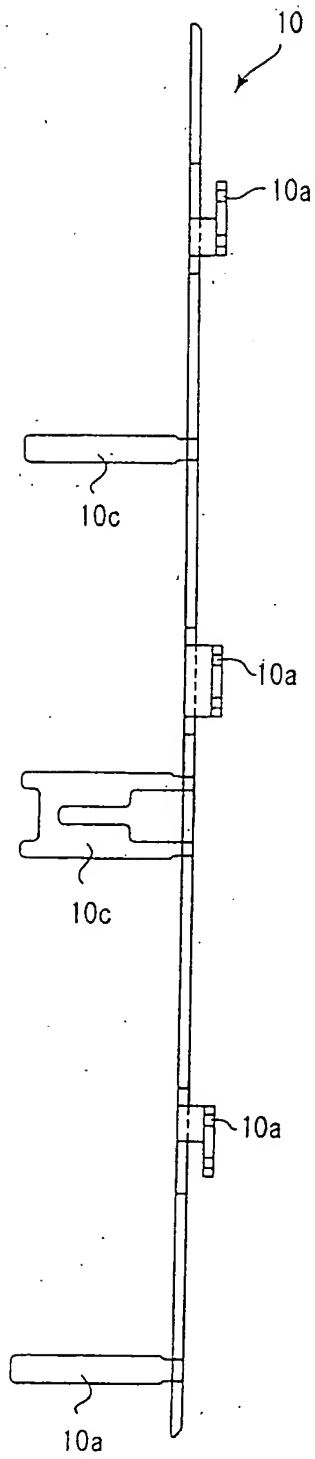
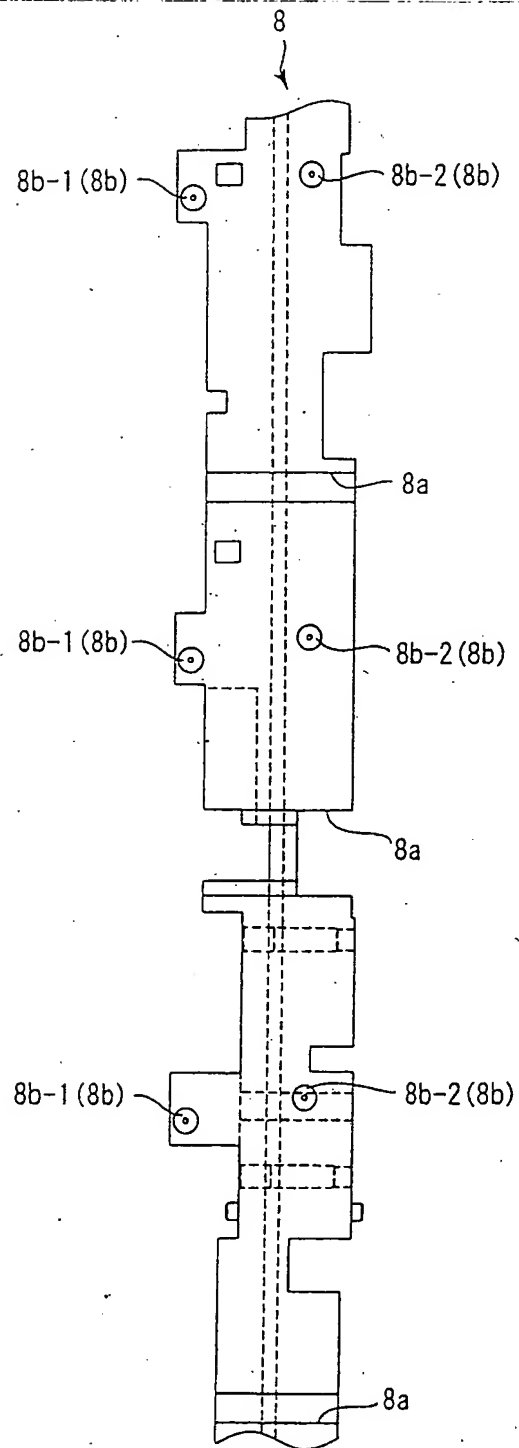
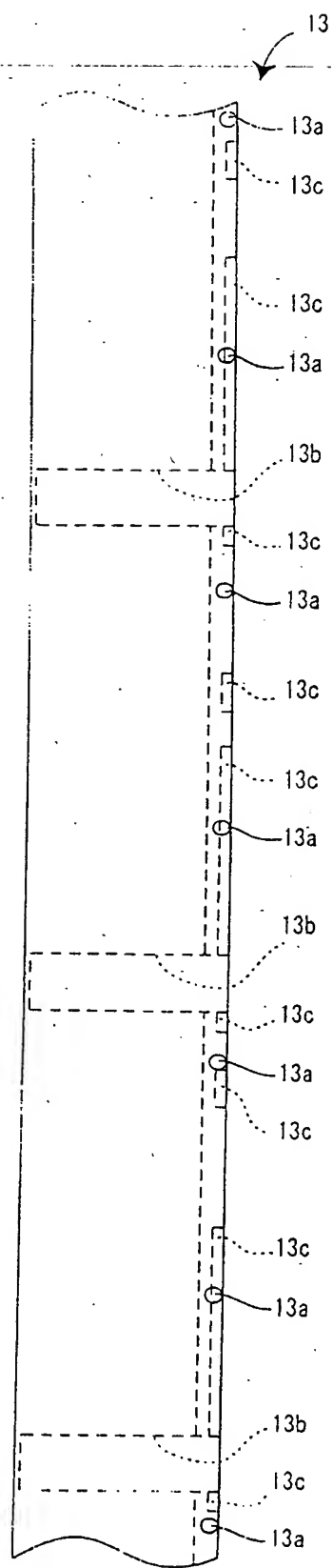


Fig. 15



F i g . 1 6



F i g . 1 7

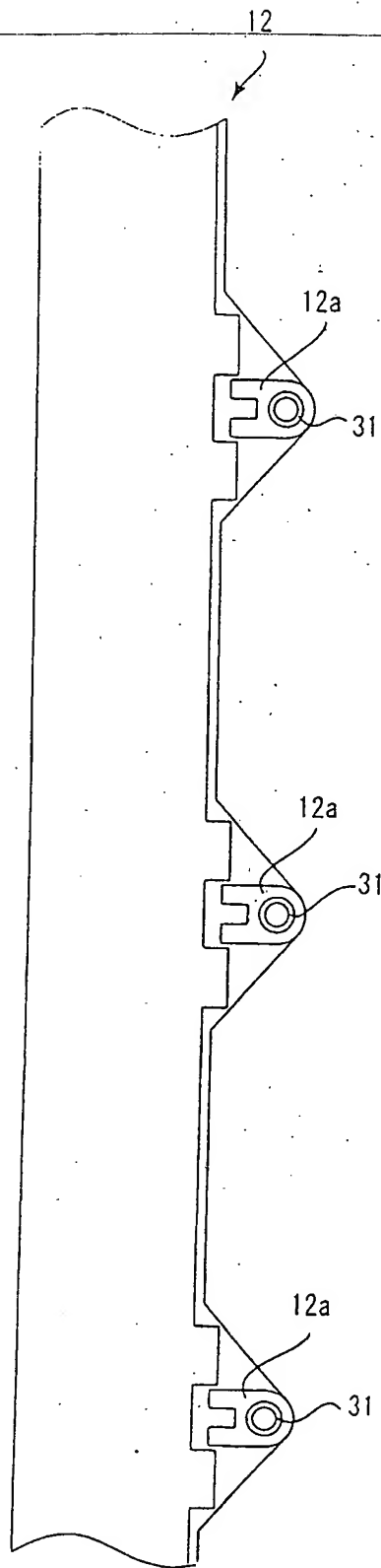


Fig. 18

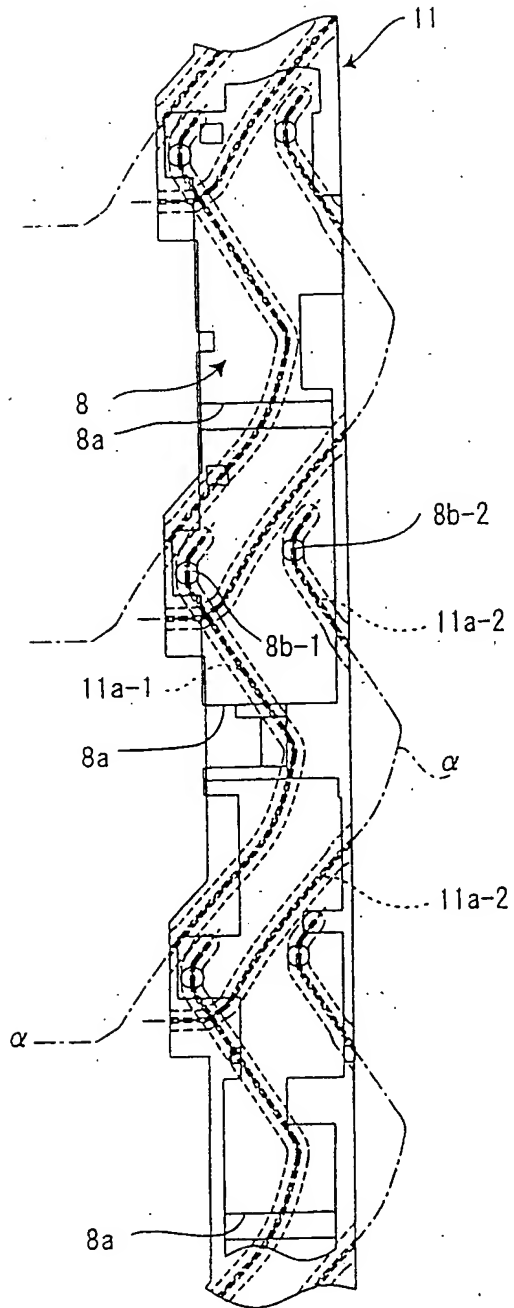
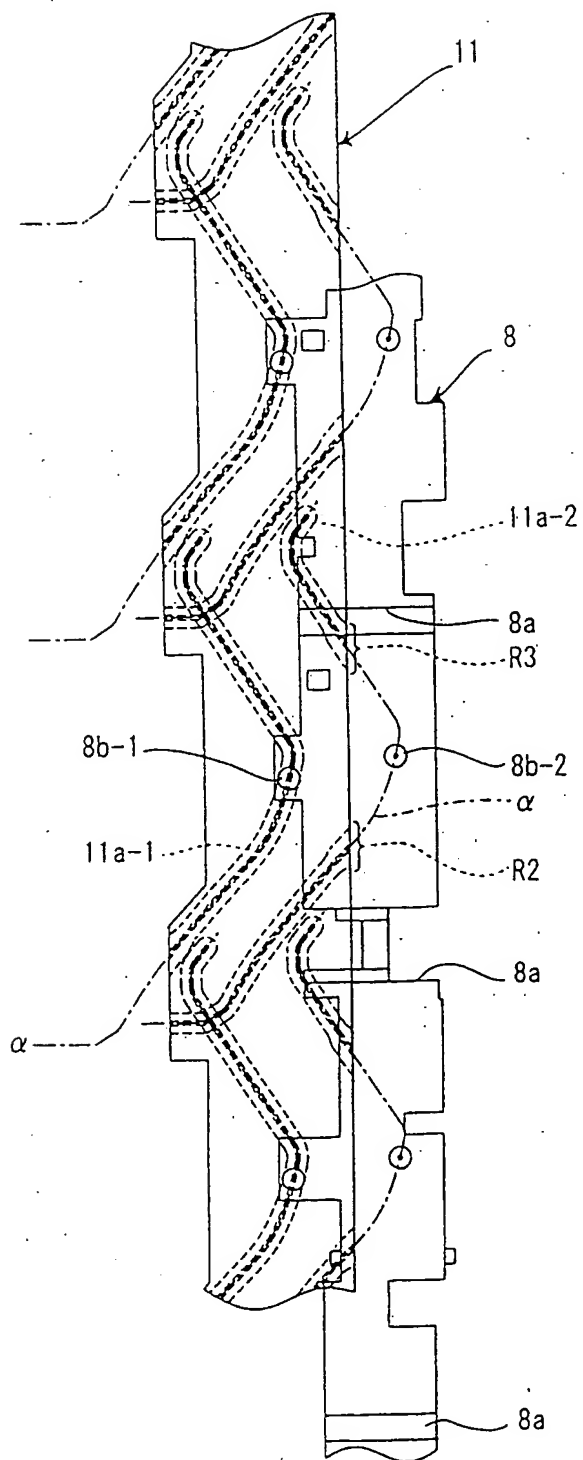
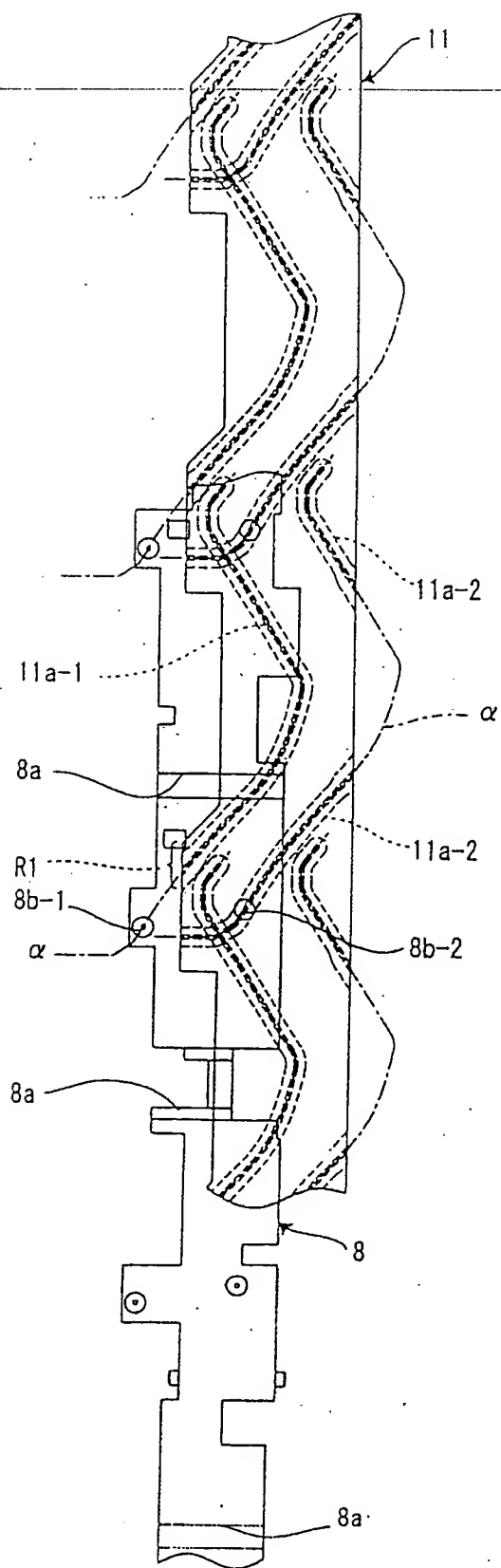


Fig. 19



F i g . 2 0



F i g . 2 1

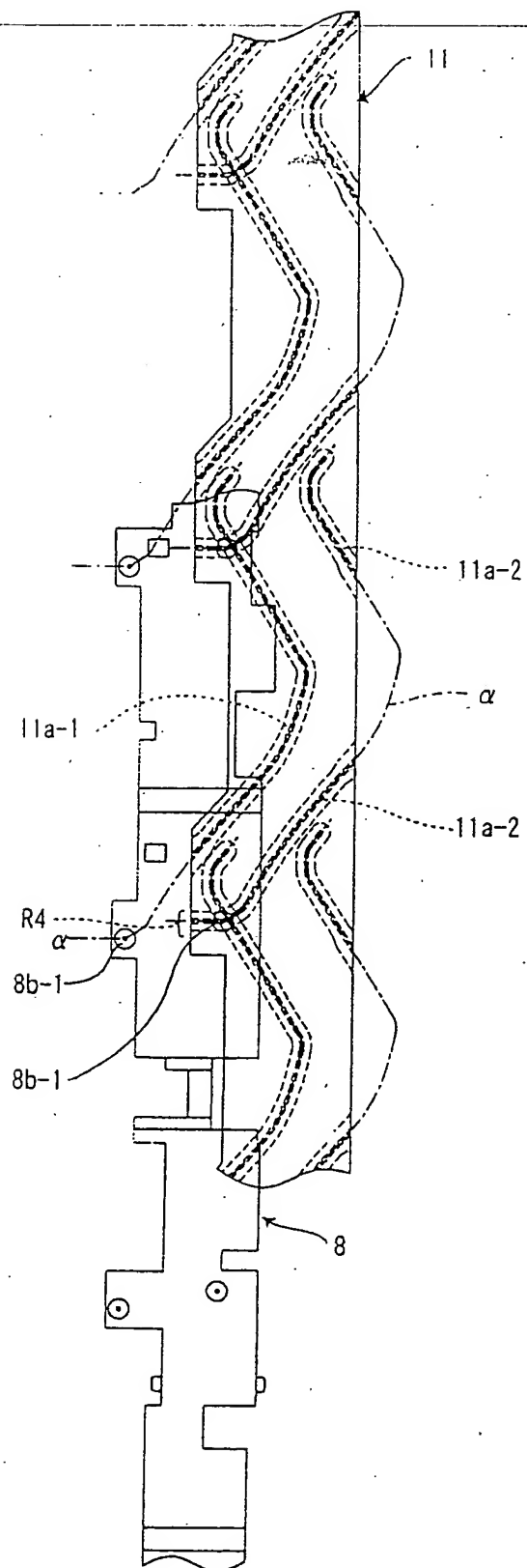
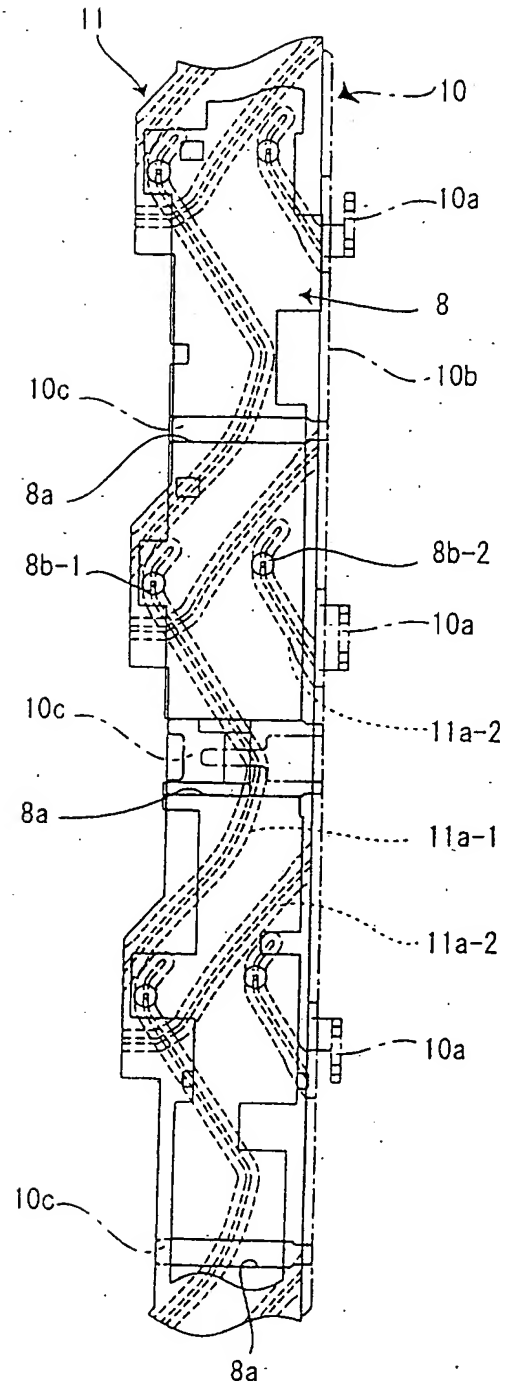


Fig. 22





F i g . 2 3

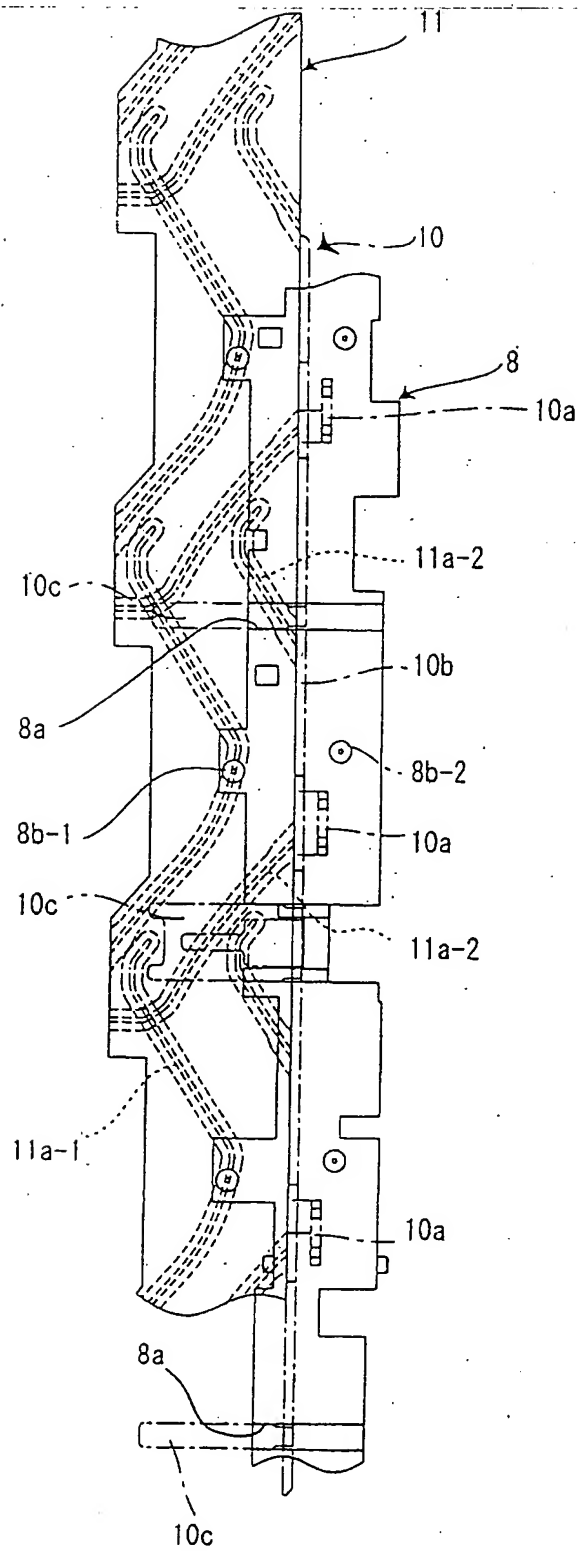


Fig. 24

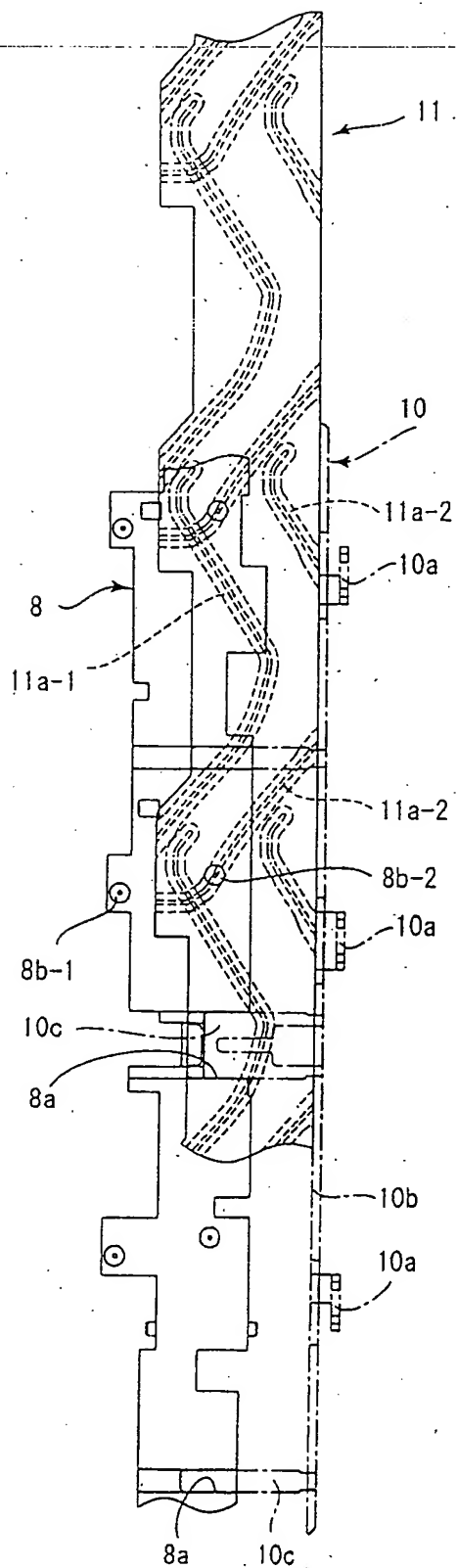


Fig. 25

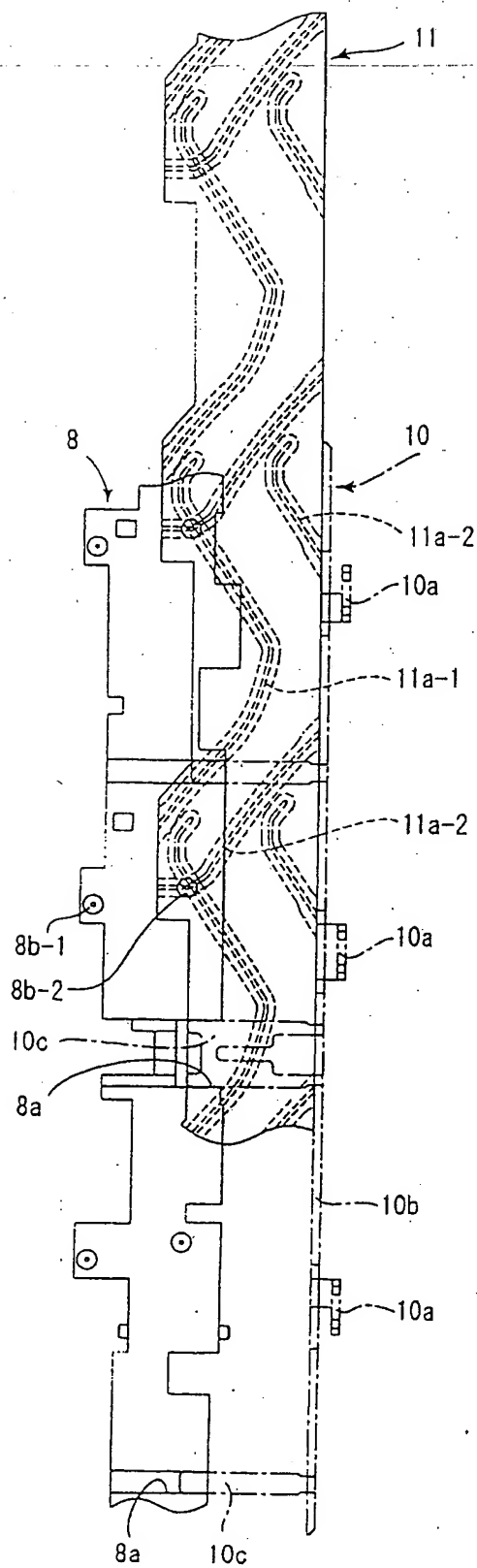


Fig. 26

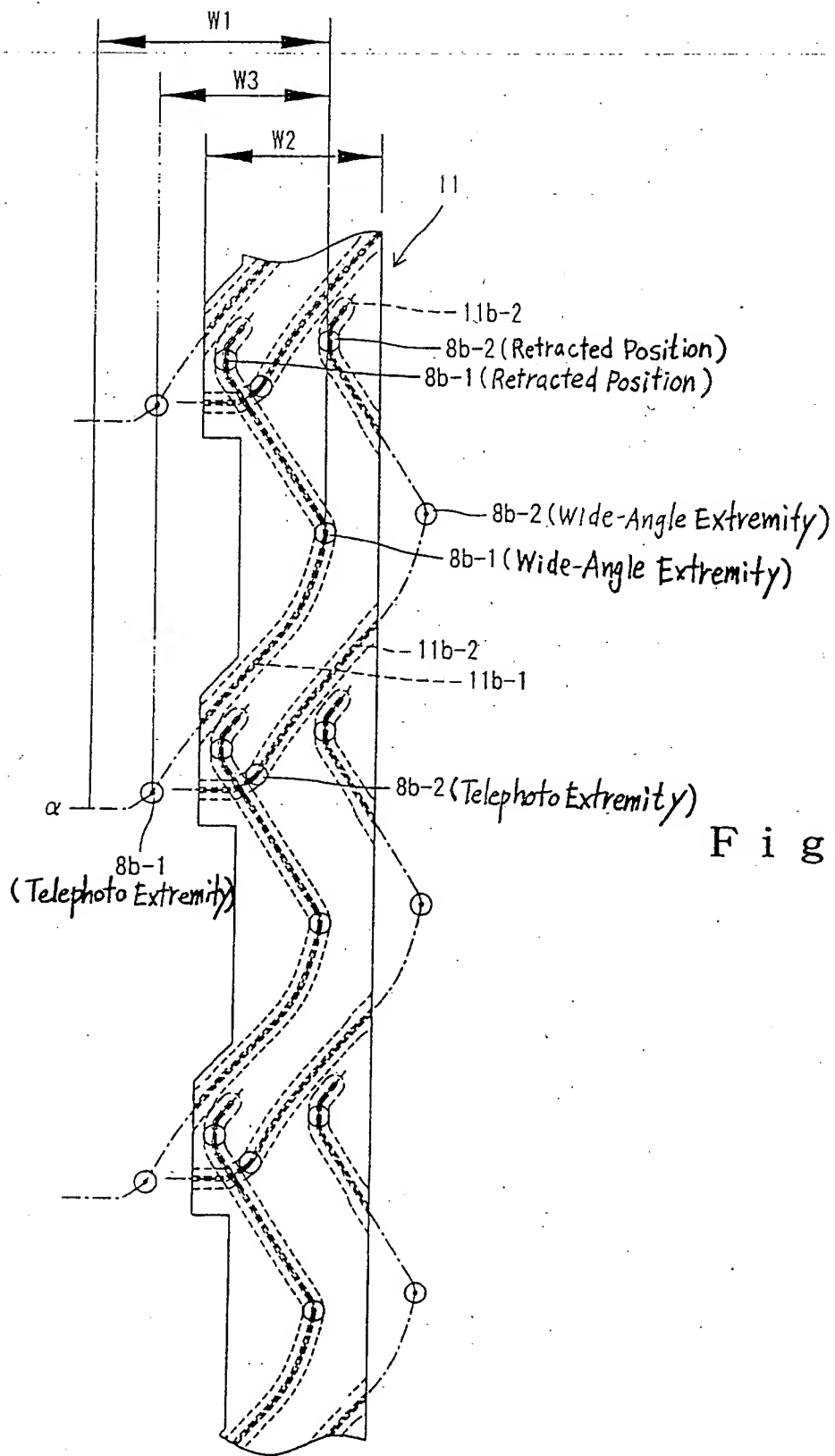


Fig. 27

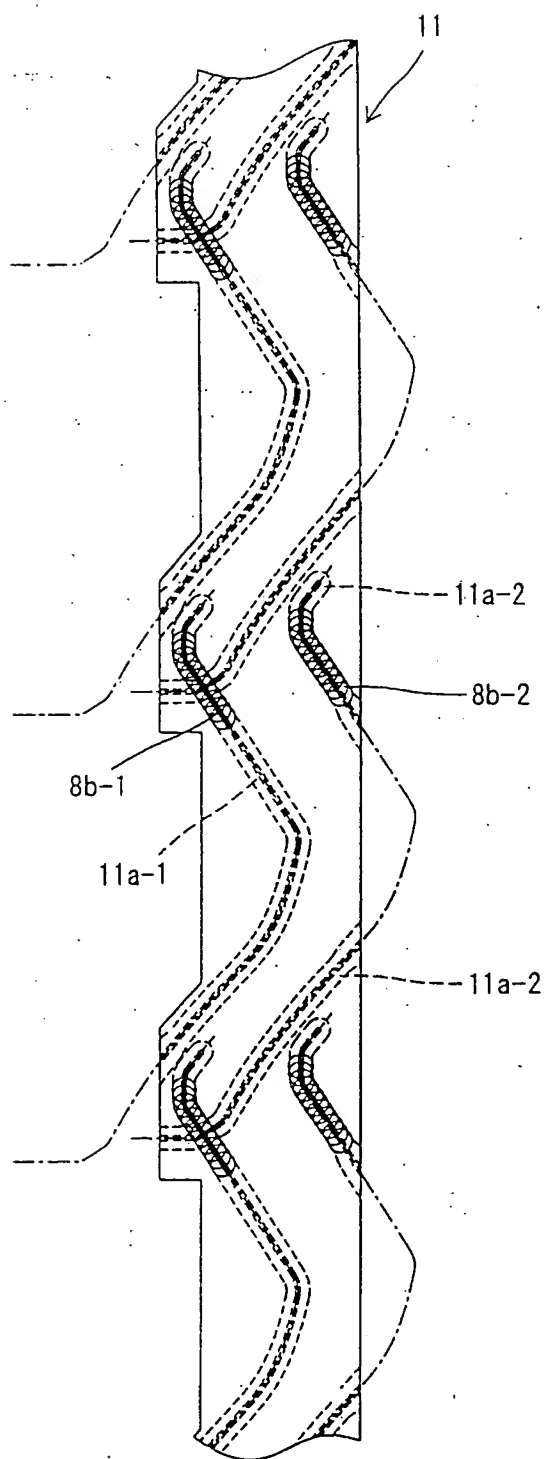


Fig. 28

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